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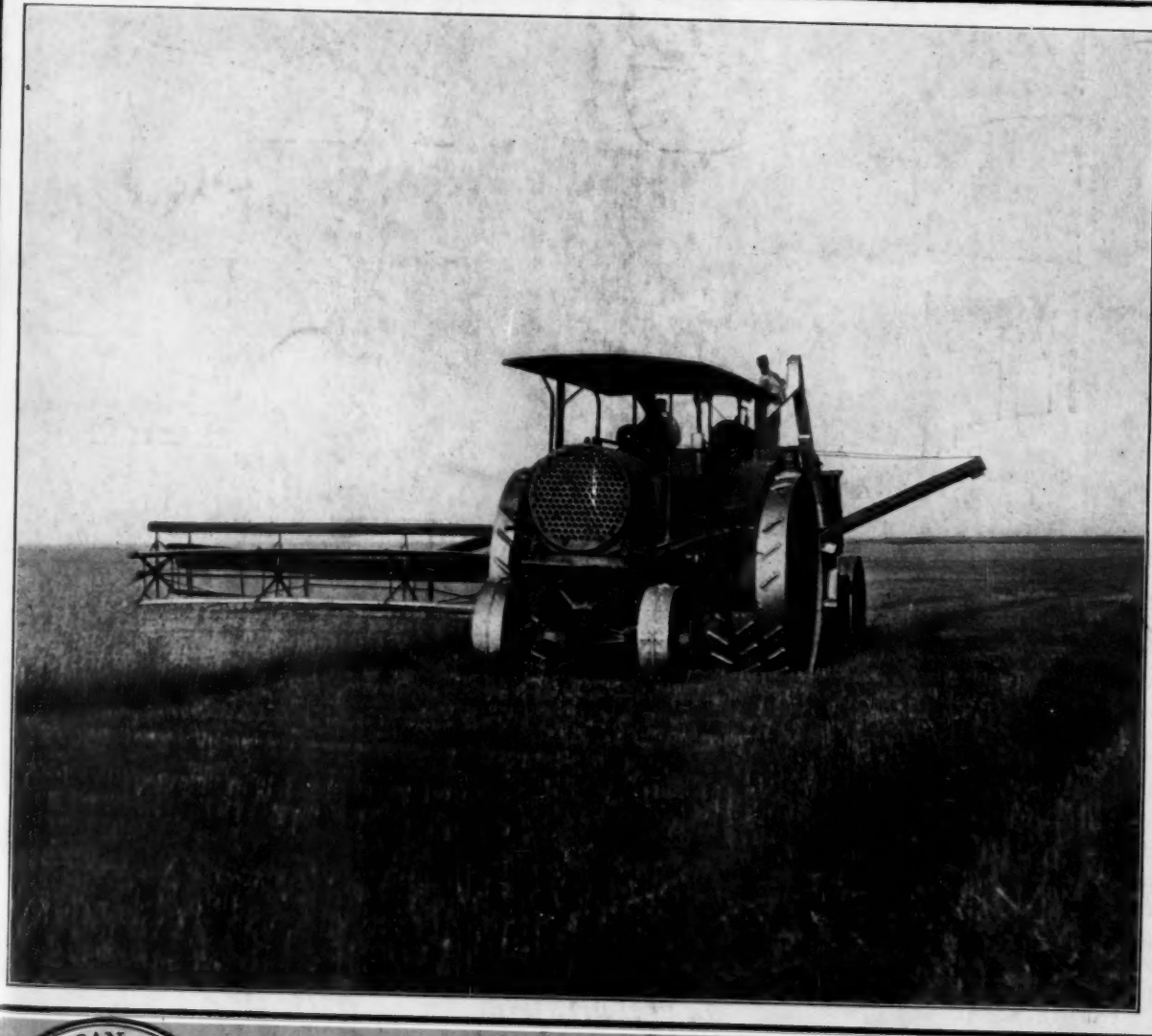
MECHANICAL ENGINEERING



October 1928

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Contributors to This Issue

T. D. Campbell, president of the Campbell Farming Corporation, Hardin, Mont., received the degrees of A.B. and M.E. from the University of North Dakota, and later received his master's degree in engineering from Cornell University. From 1905 to 1910 he served as chief engineer of the Pembina Portland Cement Co., the Grand Forks Street Railway Co., and the Northern Dakota Railway Co. For the next eight years he was president of Thomas D. Campbell Co., Los Angeles, Cal. He has been termed the "biggest United States wheat farmer," for he cultivates 100,000 acres of wheat on dry benchlands in the Crow Indian Reservation, near Hardin, Mont. Half of the acres lie fallow each year, and from the other half are produced some 500,000 bushels of wheat by a fleet of machinery and an army of men. Mr. Campbell's paper was delivered as an address at the Summer Meeting of the A.S.M.E. at St.Paul-Minneapolis.

* * *

E. A. Stewart has been associate professor of agricultural engineering at the University of Minnesota for the past eight years. He has recently resigned to accept the position of president of the Northwestern Public Utilities, Inc., an electric-utility company offering electric service to farmers and rural communities throughout quite a large territory in Minnesota. He was graduated from the University of Chicago in 1915, and was then for a while engaged in teaching. He spent three years in this capacity at the Kansas State Agricultural College. While there he did some of the first radio broadcasting in the United States and was one of the founders of the first radio-broadcasting stations in the Northwest. He has specialized on a study of the use of electricity in agriculture for the past five years, during which he has been in charge of the "Red Wing Electrification Project." He has made a study of rural electrification in Canada and Europe. He was a representative at the World Power Conference at Basle, Switzerland, in 1926. He is chairman of the Rural Electric Division of the American Society of Agricultural Engineers.

* * *

L. J. Fletcher, agricultural engineer and supervisor of agricultural sales of the Caterpillar Tractor Co., is an agricultural-engineering graduate of Iowa State College. Following his graduation in 1915 he served for one year as instructor in agricultural engineering at the State College of Washington. He then became associated with the department of agricultural engineering of the University of California where he remained eleven years, six years as head of the department. In this position, among other duties he was chairman of the California Committee on the Relation of Electricity to Agriculture. He has been connected with his present concern since the first part of 1927. This work brings him in contact with many of the larger farming projects in the United States and the application of power to ordinary types of farming in the various regions. He is a member of the American Society of Agricultural Engineers, and served as first vice-president and chairman of their Meetings Committee in 1926.

* * *

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* * *

E. H. Tenney, chief engineer of power plants of the Union Electric Light & Power Co., St. Louis, Mo., was graduated from Oberlin College in 1903 with the degree of B.A. and from Ohio State University in 1905 with the degree of M.E. He became connected with the Union Electric Light & Power Co. in 1905 as a draftsman and one year later was appointed assistant to the chief engineer of power plants, which position he held until 1919 when he was promoted to the position of chief engineer.

* * *

This Month's Cover is a photograph of a tractor-drawn combined harvester and threshing machine. It cuts the grain in a strip twenty feet wide and after threshing it, deposits it in a bin on top, from which it is removed for marketing. This is just one of the many modern agricultural machines used on Mr. Campbell's 100,000-acre farm, the operation of which is described in the leading article of this issue.

MECHANICAL ENGINEERING

Volume 50 October, 1928 No. 10

The American Farm Problem

The Present Unsatisfactory Economic Status of the American Farmer, and How It May Be Improved Through Tariff Adjustments, the Development of Inland Waterways, Better Grain Grading, and the Application of Engineering and Industrial Methods to Agriculture

By THOMAS D. CAMPBELL,[1] HARDIN, MONT.

THE condition of agriculture is the greatest economic problem before our country today. All other industries have had unprecedented prosperity and all employees have had unparalleled pay checks. Industry has been buying from itself for the past five years until its workers have hypothecated their salaries and pay checks for fifteen to thirty months, chiefly by installment buying, to the extent of five to six billion dollars per year. Meanwhile the purchasing power of the farmer has diminished nine billion dollars in eight years. The workers in industry, particularly their wives, are beginning to realize that they have assumed large future commitments and are curtailing their purchases. It is easy to see how a great industrial depression could soon develop if payrolls were reduced or eliminated. Vacuum cleaners, radio outfits, electric washers, automobiles, and many other necessities would be returned to the manufacturer because the monthly installments could not be met.

Business men, manufacturers, and other thinkers realize this condition and know that it is very necessary that the farmer become a purchaser again if we are going to maintain our national prosperity. It is a recognized fact that we cannot have continuous national prosperity without agricultural success.

THE engineer, particularly the mechanical and construction type of engineer, is going to be a big factor in the solution of the agricultural problem. He is going to do for agriculture what he has done for industry. Industry long ago accepted the advice and reports of the engineer, and recently has not only accepted his advice but has adopted him. Twenty-five years ago, when many of us were being graduated from college, the engineer was consulted and sometimes called in at directors' meetings—to be dismissed immediately afterward. Now he is invariably a member of the Board—very often the vice-president, as well as chief engineer, and there are many instances in which the chief engineer has become the president or general manager. Business men and the owners of capital are beginning to realize that the modern engineer is a good executive as well as a technically trained man.

Farming will soon be recognized as a dignified business. People will give it the classification to which it belongs, and it will attract the smart, ambitious young man. The biggest industrial opportunity in the United States today is in agriculture, and the broadest field for the technical man is in agricultural engineering.

There has always been a farm problem. The Pharoahs had it when they were building their pyramids in the valley of the Nile. The Greeks had it, the Carthaginians had it, and there was no more serious time in all of Roman history than when the farmers revolted after the second Macedonian war. The land question then was what the wage question is now to our more complex industrial society. The rift between the rich and the poor went on widening. Cheap grain was shipped in from other provinces and undersold the Italian farmer. The small farmer had no escape; formerly the mainstay of Italian society in peace and war alike, he drifted from the soil to form a degenerate town rabble, which listened to agitators and unscrupulous politicians who told him that the government owed him a living. Conditions became so serious that about the time of Augustus Caesar the Roman Government, seeking to appease the people, put an established price on grain, but history tells us that this did not solve the problem.

The Russian revolution was made possible because of the desire of the Russian peasants to own their land.

England has always had her agrarian discontent, and now we have it as the biggest and most important economic problem in our country today.

There were many good and sufficient causes for the Non-Partisan League in North Dakota. It is impossible to stampede 600,000 people into a revolt against conditions in three months, as the election of 1917 in North Dakota showed, without some injustice back of it all. It takes years of wrong or unfair practices, either fancied or otherwise, to move people into such a political revolt, and the fear now is that we may have a national Non-Partisan League if our business men and our statesmen do not give their time and attention to our own agricultural problem, for no one will deny that we have such a problem.

It is not an easy problem to solve, as it involves our entire national life, economic and social. It has many aspects, and no one suggestion will cure. The average tenant or farmer has little hope or enthusiasm. His children leave the farm as soon as they are educated or feel their obligations to their parents have been fulfilled. No woman in any other industry puts in as many hours of toil as the farmer's wife.

Few realize the magnitude of the agricultural industry and its relationship to all business. Farming as an industry is greater than all our other industries combined, and over fifty per cent of our export business consists of products manufactured from raw farm products. How important a factor this is will be seen

[1] President, Campbell Farming Corporation. Mem. A.S.M.E. Address delivered at banquet, A.S.M.E. Summer Meeting, St. Paul-Minneapolis, August 27 to 30, 1928.

when it is realized that our export business averages about $480,000,000 per month. Agriculture in the United States represents an investment of approximately $90,000,000,000. There have been years when the products of our farms sold for $20,000,000,000. This is two-thirds of our total war expense, and almost equal to the 1922 appraisal of all the railways, including terminals, in the United States. It requires more power to plow the farm lands in the United States within proper season than it does to operate all of our other industries combined, including transportation. It is not strange, therefore, that every one in the United States is more or less interested in the success of agriculture.

Many bills and suggestions have been offered, many ideas proposed, all of which have been rejected—without other proposals—much to the discouragement of the farmer. He feels that other industries, including labor, have been rather well provided for by our tariff and restricted immigration. Banking and financial interests have been well stabilized through our Federal Reserve and the McFadden Banking Bill. The necessity of a fair return for transportation has been recognized by our Transportation Act and Interstate Commerce Commission. Public-utility corporations are allowed a fair return on their investment.

Two million farmers have abandoned their homes since 1920, and the condition of the small farmer is worse than it has ever been. He receives about a dollar for 60 pounds of wheat, and the city man pays 10 cents a pound for bread. He received 10 cents a pound for pork and 70 cents a bushel for corn, while the consumer pays 50 cents for bacon. He receives two to three dollars a barrel for apples which sell for 10 to 15 dollars per barrel, and so with all other commodities except citrus fruits and wool. The margin is too great; something is decidedly wrong.

If the tariff is lowered, the manufacturer and the laborer will suffer. If railway rates are lowered, wages will be reduced and service impaired. If the Federal Reserve system and the McFadden Banking Act are repealed, credit will suffer and panic will stare us in the face—business confidence will disappear and industrial depression will follow. If cooperative marketing is advocated or government control and price fixing are suggested, all commission merchants and city organizations will loudly protest and the cry of special privilege will be raised. If the farmers endeavor to help themselves or demand the same advantages as other industry enjoys, it is socialism, unsound paternalism, or radicalism.

All of these questions are debatable, and I am not advocating or denying them. It does seem, however, that several things can be accomplished with our present laws and regulations which will solve many of the farmers' problems without new legislation or appropriation of large funds from the national treasury.

We have farmed for many years and know that the following suggestions will greatly relieve the present condition.

The Tariff and Labor

Give the farmer the same protection through our tariff as other industries enjoy, and the advantages which labor has through restricted immigration. I feel that it would be a serious mistake to reduce our tariff on manufactured goods or to lessen the restrictions on immigration, but it is only fair, as long as the farmer pays his share of this industrial and labor protection, that our flexible tariff be adjusted to give him similar advantage on his products.

For instance, we have a tariff of 42 cents a bushel on wheat—certainly high enough for any one—but most wheat imported is milled in bond and 40 cents per bushel rebated.

Economists, free traders, manufacturers, and bankers interested in these mills unite in saying that all this grain would go to Europe from Canadian mills if we did not grind it, and, as a result, a reduction in rebate would make no difference. This would be true if we produced enough hard spring wheat, high in protein, similar to what we import from Canada, but we do not. A reduction of this rebate would increase the price of our Dark Hard Northern Spring wheat, and it is the first law of merchandising that if the better goods are increased in price, the other grades will increase accordingly or in proper proportion.

About twenty-five years ago, when the Standard Oil Company first began selling kerosene to the Chinese in five-gallon tin cans, it used to ship tinplate into this country for the manufacture of these cans by the boatload. The cans were manufactured, filled with kerosene, and shipped to China duty free, as the manufacture was made in transit. The steel industry was well enough organized and strong enough to prevent this. It is not altogether a parallel case to milling wheat in bond, but there is certainly some analogy.

We have a duty of 45 cents a bushel on flaxseed, but the manufacturers of linseed oil crush this seed in New York, ship the oil cake to Europe, where it is sold for five dollars a ton less than it will bring in this country, and by so doing they get a rebate equivalent to 15 cents per bushel on the imported flaxseed, making the duty but 25 cents per bushel, and at the same time depriving the American cattleman of the use of this cheap oil cake.

Tons and tons of molasses are imported into this country yearly from Cuba for the manufacture of industrial alcohol. This is a by-product of their raw sugar. Cuba is not an industrial country and this by-product is purchased very cheaply. It comes in practically duty free and takes from our corn farmer a market which he used to have for his low-grade corn, estimated by some authorities as equivalent to 100,000,000 bushels. As a result this poor corn drifts to terminal markets, and because it can be delivered on future contracts at a reasonable discount it keeps the price down on 2,000,000,000 bushels of corn. This condition can be changed with our present laws and regulations.

No one works harder than the dairy farmer. He averaged last year for the entire output about $60 per cow, which included the cost of the cow's feed, his labor, and the sale of the product. Yet we imported for the twelve months ending September, 1927, 17,000,000 pounds of cheese, $4\frac{1}{3}$ million gallons of cream, 4,000,000 gallons of milk, 6,000,000 pounds of condensed milk, and 500,000 pounds of butter. It is only recently that we had any duty on milk and milk products, and there is very little now on milk, but when manufactured into butter the duty is 12 cents per pound—protection for the manufacturer but none for the producer.

The United States imported for the year ending June 30, 1927, over two and one-half billion dollars' worth of agricultural and forest products, one billion of which can be produced in our own country, such as soy beans, eggs, milk, hides, buckwheat, rice, tobacco, flax, etc. The tariff should be increased on these products so that we could afford to raise them. Recently the duty on cast iron and structural steel was raised 50 per cent because a little cast iron and steel was coming in from Belgium and Germany.

Railway Rates and Waterways Transportation

A discussion of the farm problem would not be complete without some reference to transportation, as it is such a big factor in that business. During the period of recent low prices of grain it required practically one-third of the gross selling price of our grain from Montana to pay for the transportation costs. No other industry in the United States could stand such a proportionate charge, with the possible exception of heavy commodities such as iron ore and coal, which are mined by machinery at a

very low cost. I do not favor a reduction of railway rates as the item of service is a great part of the cost, and in order to get this service, rates must be in accordance. There can be, however, an adjustment of rates without any resultant reduction to the transportation companies. For instance, any one knows that the movement of a car of cattle two thousand miles to market is more hazardous and expensive than that of a car of wheat, and the value at present prices is five times as much. Still it costs twice as much to get a car of wheat to market as it does a car of livestock.

Railway companies have always been friendly to agriculture. It is to their best interest to be so. Our transportation facilities are now overtaxed and will continue to be. The one great relief for this congestion without discrimination against any railway line will be the development of our inland waterways. All big railway systems in the United States either cross the Mississippi and Missouri or reach them. Grain and other commodities from the Northwest can be delivered at New Orleans for distribution east or west—east to Europe or west through the Panama Canal. Such an improvement would at the same time solve to a great extent our flood problem, and the entire Northwest would profit by it. Grain is transported in Canada for approximately one-half what it costs the farmer in the United States for the same distance. Sometimes you hear the remark that the railways in Canada are government-owned and that is why it is possible, but the Canadian Pacific is not government-owned. It transports the greatest bulk of Canadian wheat, and its earnings are comparable to those of any railway in the United States.

Boards of Trade and Grain Grading

Many farmers are of the opinion that boards of trade are unfriendly toward them and try to depress the price. This is not so, but there are of course members of boards of trade who manufacture a finished product from the raw farm product, and they very naturally buy that commodity as cheaply as they can and oppose any legislation which will increase the price. They are, however, a very small percentage of the membership.

The established rate for selling grain on the boards of trade is very low, about $1^1/_2$ cents per bushel, and is the cheapest part in a farmer's operations. Most commission houses will get for the seller in better grades, reinspection, better markets, and better prices a sum equal to several times the selling cost.

Practically all grain purchased by line elevator companies, terminal elevators, and millers is "hedged." This means that a bushel is sold short on the market for every bushel purchased. Bankers require this in order to keep the account balanced. A part of this hedging is done during the time the farmer is marketing his grain, and often when the speculator is selling short. The farmer is selling also, so we have practically the sale of four bushels of grain for every one produced, not including speculation. A great portion of Canada's crop is purchased in Canada, delivered to England and Europe, and sold short in the United States. There is no duty on short sales, and we have to absorb all of this European hedging pressure each year without any duty protection. This is a subject which is worthy of considerable thought.

The Government should establish grades representing the highest grade, and buyers should not be permitted to trade in grades having more value. To illustrate: All terminal buyers in the Northwest trade in four grades—namely, choice, extra choice, fancy, extra fancy—higher than Dark Northern Spring, the highest grade recognized by the Department of Agriculture and the highest grade which can be put on a storage ticket. These four grades vary in value from five to thirty cents more than Dark Northern Spring. This causes a loss to all farmers in the spring-wheat area estimated at an average of 15 cents a bushel if they sell in less than car lots, and most wheat is sold in less than car lots. The farmer will take a storage ticket for his wheat. It may be extra fancy. The ticket by law cannot read better than Dark Northern Spring. The next day, next week, or next month the farmer sells his wheat and presents his ticket. He is paid the card price for Dark Northern Spring, while his wheat may be worth 25 cents more. This can be changed very easily and should be done, as the use of higher grades is only a subterfuge to buy cheaper.

Some attention should be paid to the regulation discounts, etc. which apply to grain which can be delivered on future contracts, as the future price determines the daily price card, governing the purchase of all grains. This grading of grain alone will go a long way toward solving the spring-wheat-growers' problem.

Farm Representation

Agriculture should be represented on all national boards, especially farm loan banks, intermediate credit banks, and interstate commerce commissions. An industry which represents one-third of our total railway tonnage surely has a right to representation, but he must not be a farmer who fails to appreciate service. Moving the major portion of a crop of approximately 800,000,000 bushels of wheat each year, together with our other farm products, in approximately three months, requires an investment in cars, motive power, and organizations scarcely realized by most people.

Industrialization

The foregoing suggestions are all big factors in the solution of the present farm problem, but more effective and positive still will be the application of engineering and industrial methods. There are but two types of successful farming in the United States today under present economic conditions: namely, the small farm on which the farmer and his family do all the work and there is no payroll; and the large farm operated on an industrial basis with economical units, skilled workmen, high wages, and scientific business management. All other industry has increased its output per man many times. The economical unit is well established. What chance has the farm to engage skilled men when they can earn several times as much in the city? What inducement is there for the farmer boy with brains to remain on the land when he can be more prosperous in the city and where capital will finance his ideas? The farmer is like every other manufacturer who has foreign competition or a surplus. He must either reduce his costs, get tariff protection, or limit his production. We have too many people on the land now. Less than 20 per cent of our population will be on the farms in another twenty years. This farm population will drift to the city to meet our ever-growing industrial demands.

The farmer is trying to compete in an unorganized way with the thoroughly trained and organized purchasers of his products. He needs the support of the business man and the Government until he can better organize his production and marketing. He is not entitled to any special privilege nor extra consideration, but the same recognition, the same protection, and the same advantages that other industries enjoy through our national laws and regulations will give him unprecedented prosperity.

The engineer, particularly the mechanical and construction type of engineer, is going to be a big factor in the solution of the agricultural problem. He is going to do for agriculture what he has done for industry. Industry long ago accepted the advice and reports of the engineer, and recently has not only accepted his advice but has adopted him. Twenty-five years ago, when many of us were being graduated from college, the engineer was consulted and sometimes called in at directors' meetings—to be

dismissed immediately afterward. Now he is invariably a member of the board—very often the vice-president, as well as chief engineer, and there are many instances in which the chief engineer has become the president or general manager. Business men and the owners of capital are beginning to realize that the modern engineer is a good executive as well as a technically trained man.

Farming will soon be recognized as a dignified business. People will give it the classification to which it belongs, and it will attract the smart, ambitious young man. The biggest industrial opportunity in the United States today is in agriculture, and the broadest field for the technical man is in agricultural engineering.

Operating a 95,000-Acre Wheat Farm

Thomas D. Campbell, of Montana, Employing Engineering Methods and Ingenious Combinations of Power-Driven Machines on a Tremendous Scale, Operates With Skilled Men on an Industrial Basis

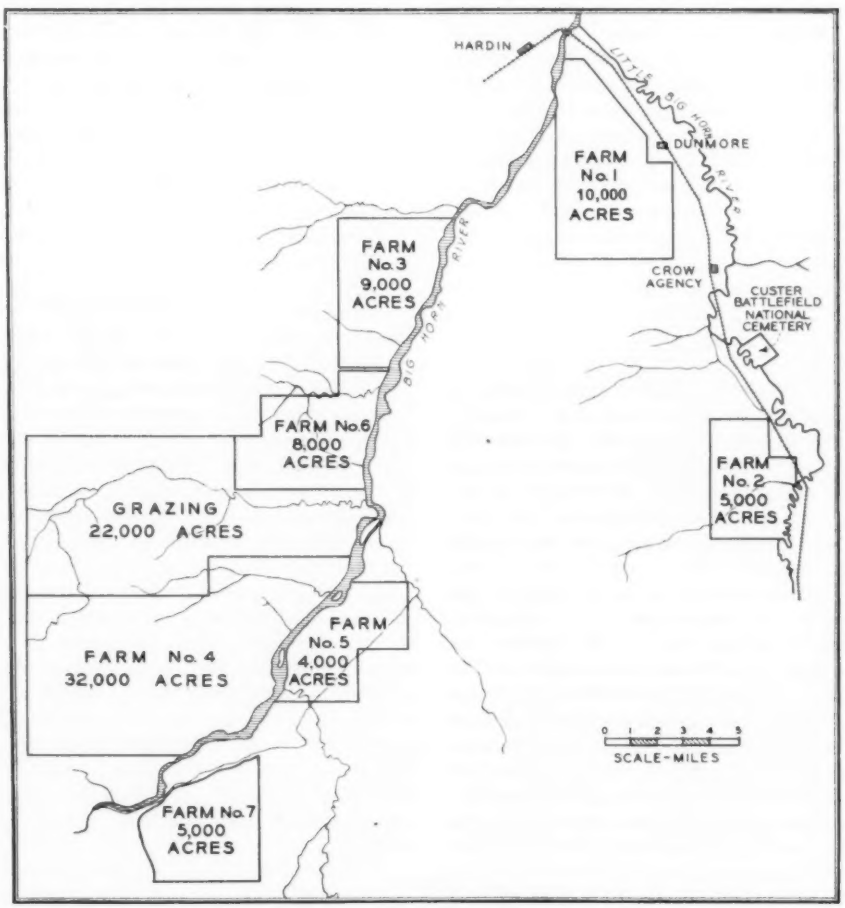

FIG. 1 MAP SHOWING LOCATION AND ARRANGEMENT OF THE 95,000 ACRES OF THE CAMPBELL FARMING CORPORATION

"THE great industrial opportunity today is in agriculture." Thomas D. Campbell has proved the truth of this his own statement on the 95,000 acres of the Campbell Farming Corporation. By the intensive use of modern machinery, operated by thoroughly organized, highly skilled, and well-paid men, he has shown that producing wheat and flax at a profit does not depend on receiving the highest prices in a fluctuating market for these commodities. His operation is conducted on the same basis as that of any other great industry. He has used engineering skill and judgment to build his own farming industry, and he looks to engineering and industrial principles to play a large part in the solution of the American agricultural problem.

As the son of a farmer, Campbell's young dreams were of reducing the drudgery of farm work and of bringing vast acreages to fruitful harvest by the employment of great units of mechanical power. He therefore studied mechanical engineering, later being graduated from the University of North Dakota and then taking post-graduate work at Cornell. His vision of machinery in large-scale farming was realized during the war when he was drafted to grow wheat for the allied armies on 7000 acres of the Crow Indian reservation in southern Montana. He was successful in this venture, and after the war organized the Campbell Farming Corporation which operates 95,000 acres near the scene of his first success.

Fig. 2 Fifteen Tractors Drawing 60 Disk Plows

Fig. 3

Fig. 4

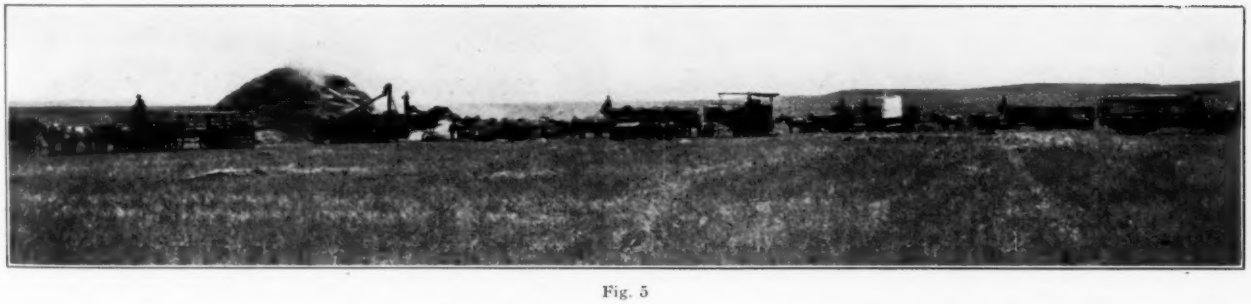

Fig. 5

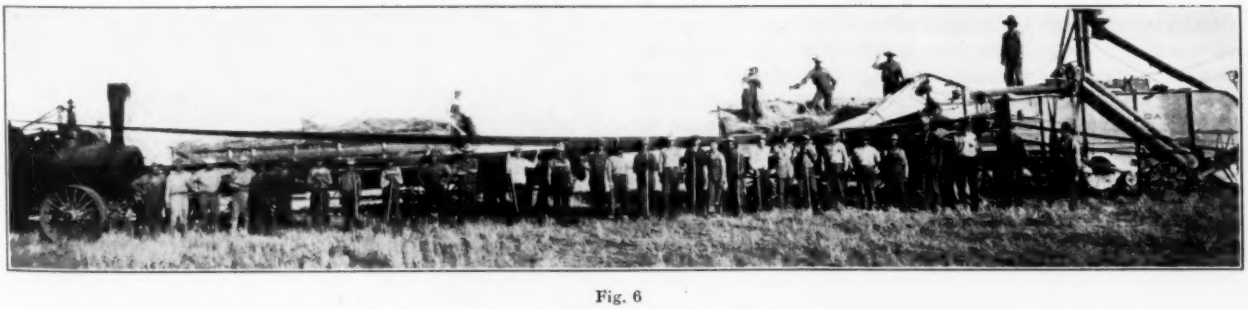

Fig. 6

Figs. 3–6 Harvesting Methods Now Becoming Obsolete
(Fig. 3, Reaping. Fig. 4, Shocked Wheat. Fig. 5, Threshing. Fig. 6, The Threshing Crew.)

American inventors have led the world in providing machinery for the use of farmers. Today an American farm without a goodly quota of machinery is unknown. Campbell's success is unique not because he uses machinery but because he uses it on a tremendous scale and with the organization necessary to complete the operations on his vast acreage in good season. He likens large-scale farming to an annual construction contract with penalty and bonus clauses which place a premium on engineering judgment and ability to get things done. He has sufficient equipment to plow a thousand acres a day and sow and harvest

FIG. 7 NINE COMBINES CUTTING AND THRESHING WHEAT AS THEY MOVE
(The first seven store the grain on the machine; the last two, of an older model, place it in wagons drawn at the side of the machine.)

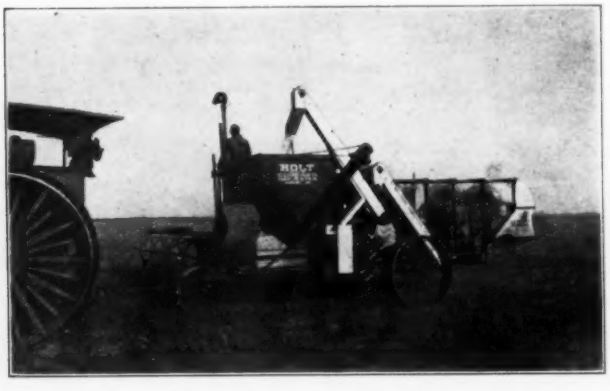

FIG. 8 COMBINE, SIDE VIEW
(Note the separate driving motor in front and the storage bin on top. This bin may be emptied into the grain truck brought alongside.)

FIG. 9 COMBINE, REAR VIEW

two thousand acres a day. In dry farming, which is the type he practices, the operations must be carried to completion when rain and weather are right. He must frequently save his crop from hail. His success is therefore measured by his ability to use his equipment to the full during the available working periods.

FARM LOCATION

Campbell demands the same quality of data on which to base estimates of probable success in farming that an engineer demands for estimating the feasibility of a hydroelectric plant or any other engineering project. In selecting his farm lands, he studied rainfall and hail records, topography (important for large-scale mechanical operation), soil productivity, and proximity to transportation systems and markets, and his choices have justified his judgment. The lands are located along the Big Horn and Little Big Horn Rivers (Fig. 1), and are divided into seven farms. One is irrigated, while the others are dry-farmed.

FARMING METHODS

The crops grown are wheat and flax, a diversification which enables Campbell to face low prices for either of the two crops. The secret of successful dry farming is to keep the surface of the soil pulverized after plowing and during the early days of growth so that the natural rainfall is conserved. About 65,000 acres of the 95,000 have been plowed. Crops are grown in two consecutive years, and the third year the ground lies fallow. Two-thirds of the plowed land is therefore in crop each year. The first plowing is done with moldboard plows to a depth of four inches. The quantity of seed that will mature under probable rainfall is sown and the soil packed in by weighted packers attached to the seeding machines. Harrowing follows at intervals to keep the weeds down and work the surface. After the second crop, the fields are allowed to grow wild one season. Then in the fall the growth of from one foot to eighteen inches is plowed under by disk plows. The broken ground permits the fall rains, snow, and spring rains to percolate into it. The plowed-under vegetation provides the necessary nitrogen for fertilizer. No other fertilizer is used except the straw that falls after the harvesting. Tractors are used exclusively in these operations, one tractor drawing four gang plows, five seeders, and five harrows.

In harvesting, Campbell uses the combined reaper and thresher, known as the "combine," Figs. 7, 8 and 9 which has recently come into widespread use. The combine offers many economies over the previous method of binding the grain, placing it in shocks to cure, and then hauling it to the threshing machine. The threshing operation was costly and brought with it labor problems. The combine threshes as it reaps, and eliminates many intermediate steps and handlings. It saves the troublesome binding operation on the reaper with its expense for twine, and eliminates the need for shocking, loading, and hauling the grain to the threshing machines. The illustrations on page 749 show the two methods. The difference in labor required is apparent.

Combine operation requires some definite conditions if its economies are to be realized. The field of grain must be uniformly ripe and free from weeds, and the grain itself should thresh out dry. Flax is especially troublesome, because when the seed is ready to thresh, the stalk is green and stringy and will stick in the combine. To offset these objections Campbell worked out his "windrow method" (Figs. 10–12). The grain is cut by units of four ten-foot reapers drawn by one tractor. The reapers have their bundling devices stripped off and extension carriers substituted. The first reaper in the unit drops the grain in a row, the second has a carrier which drops its grain in the same row, the third reaper has a still longer carrier, as has the fourth, so that the products of the four machines fall in one windrow. These four reapers are operated by one man, who moves from one to the other on a running board and signals the tractor operator by a bell cord. The grain dries in the windrow and then a special combine is used with a hay loader in place of the usual grain-cutting mechanism. As the combine is drawn along, the loader picks the grain from the windrow and delivers it to the combine, where it is threshed and placed in the storage bin on the machine or in a wagon drawn at the side. The combine, normally expected to cut and thresh the grain from a twenty-foot strip, is by this method threshing the grain cut from a forty-foot strip. This pays for the cost of going over the ground the first time to cut the grain and pile it in the windrow. The windrow method has thus made combine economies available for all crop conditions. Campbell has patented it and placed it at the disposal of American farmers.

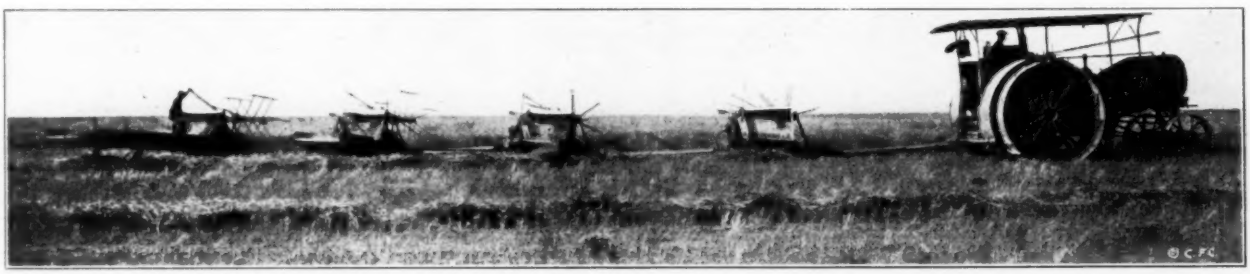

FIG. 10 REAPING FOR THE WINDROW METHOD OF COMBINING

FIG. 11 COMBINING FROM THE WINDROW, REAR VIEW

FIG. 12 COMBINING FROM THE WINDROW, FROM THE FRONT

LABOR POLICIES

The development of the windrow method is typical of the manner in which Campbell has largely done away with unskilled hand labor on his farms; instead he maintains a constant force of about two hundred skilled men for the farming season, which usually extends from April 1 to December 1. He believes in high wages with a bonus for performance, and has not lacked for good men, applications coming to him from all over the country. Each man is assigned to his own machine and is held responsible for its care and operation. Depending upon the type of machine, a bonus of from 7 to 10 cents per mile is paid for every mile it traverses. Lost tools and unnecessary breakages are charged to the operator and deducted from his accumulated bonus. Farming is necessarily a sunrise-to-sunset operation, and in harvesting time the machinery may be in the field sixteen or more hours a day. Overtime and extra mileage are paid for, but no extra time is allowed for oiling and for minor adjustments. During the off season the men go to the cities or seek temporary employment. The foremen and managers are kept busy during this time on equipment maintenance.

EQUIPMENT AND ITS MAINTENANCE

The equipment used in carrying on this large-scale operation presents an amazing total. It comprises 56 tractors totaling 3000 hp., 500 plows of various types, 600 twelve-foot drills, 72 binders, 21 combines, and 11 threshing machines now obsolete. For transportation there are 200 wagons, 12 motor trucks, and 10 automobiles. Farm work is severe on this equipment and maintenance is a serious problem. All of the equipment is gone over thoroughly during the winter, but breakdowns are frequent in tractors and farm machinery which is operating at full load practically 100 per cent of the time, and the wheels must be kept turning. Light running repairs are made in the field, but a well-equipped shop manned by skilled men is located at Hardin to handle the heavy repairs. Here a forge shop, complete welding equipment, machine shop, wood shop, and brass foundry are ready to overhaul equipment and place it back in the field in the quickest possible time. Overhauling is done on a production basis, tasks are set for overhauling the different types of machines, and a line of jigs, fixtures, and special cutting tools are ready to carry out the most frequent repair operations. The shop also contributes greatly to the economy of maintenance by

CAMPBELL FARMING CORPORATION

MANAGER'S DAILY REPORT UNIT NO. One RESERVATION Crow DATE May 28th, 1928

TRACTORS

ENGINE NAME	ENGINE NUMBER	DRIVER'S NAME	MACHINE OPERATOR'S NAME	KIND OF WORK	AMOUNT AND KIND OF EQUIPMENT PULLED	GASOLINE	OIL	WATER	MILES RUN	ACRES WORKED	HOURS ON WORK	TIME LOST	REASON FOR LOST TIME	REMARKS
A.a. T	2067	Wm Read	T. Price	Plowing	8 Plows & Rocker	30			8	8	6	None		
" " "	2434	B. Williams	E. Flynn	"	" "	15			8	8	"	"		
" " "	1739	G. Holmburg	R. Lyman	"	" "	20			8	8	"	"		
" " "	2952	A. Schmitt	H. Anderson	"	" "	35			7	7	"	1	Broken Drag Bar	
" " "	2484	J. Lockren	O. Page	"	" "	15			9	9	"	None		
" " "	2071	J. Walker	F. Snodgrass	"	" "	30			7	7	"	"		
" " "	2494	J. Leiby	J. Erickson	"	" "	30			8	8	"	"		
" " "	2468	C. Holliman	W. Franklin	"	" "				6	6	"	"		
" " "	2073	H. Schiel	B. Burnes	"	" "	15			7	7	"	"		
" " "	2445	J. Palmer	L. Charle	"	" "	30			7	7	"	"		
" " "	1975	C. Gunetha	E. Granes	"	" "	10			8	8	"	"		
" " "	3119	M. Davis	L. Davis	"	" "	30			8	8	"	"		
" " "	2450	A. Erpenbach	J. Macabee	"	" "	25			7	7	"	"		
" " "	2490	F. Auckley	A. Beachem	"	" "	30			8	8	"	"		
" " "	1863	L. Miller	J. Edwards	"	" "	15			6	6	"	"		
" " "	1939	C. Buchanan	B. Calkins	"	" "	30			8	8	"	"		
" " "	2441	L. Conklin	E. Arlt	"	" "				7	7	"	"		
" " "	1653	R. Calkins	M. Calkins	"	" "	40			8	8	"	"		
TOTALS						400			135					

ACREAGE

	PLOWED	DISCED	DRILLED	HARVESTED	THRESHED	LEVELED	IRRIGATED	SHRUMED
TOTAL LAST REPORT	2943	3359	8					2950
ACRES WORKED TODAY	135							
TOTAL FOR SEASON	3078	3359	8					2950

SEEDING OR HARVESTING

	WINTER WHEAT SEEDED	WINTER WHEAT HARVESTED	SPRING WHEAT SEEDED	SPRING WHEAT HARVESTED	FLAX SEEDED	FLAX HARVESTED	OATS SEEDED	OATS HARVESTED	BARLEY SEEDED	BARLEY HARVESTED	ALFALFA SEEDED	ALFALFA HARVESTED
TOTAL LAST REPORT	3895		8									
TODAY												
TOTAL FOR SEASON	3895		8									

THRESHING

	WINTER WHEAT BUSHELS	SPRING WHEAT BUSHELS	OATS BUSHELS	FLAX BUSHELS	BARLEY BUSHELS	ALFALFA BUSHELS	
TOTAL LAST REPORT							
THRESHED TODAY							
TOTAL FOR SEASON							

AUTOMOBILES AND TRUCKS

KIND	NUMBER	DRIVER	KIND OF WORK	WORKING HOURS	TIME ON REPAIRS	MILES	GASOLINE	OIL	CASINGS USED	TUBES USED	OTHER REPAIRS
FORD TON TRUCK	T/15726 HOME	L. COTHREN E. HODGES	HAULING	12 17			7 8	2 2	1	1	30 x 3½
" "	T-15729 HOME	J. REEVES O. STRUTHERS	"	11 10			6 4	2 1			
" "	"	C. MILLER L. ANDREWS	"	5 6			5 4	3 1			
HAYNES	"	P. ROACH	"	12			5	1			
TOTALS							39	12 qts			

GENERAL INFORMATION

CROPS PLANNED FOR 1928			EMPLOYEES		MEALS		WEATHER		
SPRING WHEAT	8	ACRES	MANAGERS	1	BREAKFAST	42	THERMOMETER DEGREES AT P.M. A.M.		ANY ACCIDENTS TODAY? GIVE FULL REPORT
WINTER WHEAT	3895	"	FOREMAN	2	DINNER	45	CLEAR		
FLAX		"	CHIEF MECHANICS	1	SUPPER	45	FAIR	✓	
OATS		"	BLACKSMITHS		EXTRA LUNCHES		CLOUDY	✓	HAVE YOU RECEIVED ANY NEW EQUIPMENT?
SUMMER FALLOW	4000	"	COOKS AND HELPERS		TOTAL	132	RAIN		HAVE YOU RECEIVED ANY EQUIPMENT FROM OTHER UNITS?
NON-TILLABLE		"	TRACTOR DRIVERS	18	TIME OF MEALS		SNOW		HAVE YOU DELIVERED ANY EQUIPMENT?
NOT USED THIS SEASON		"	PLOW MEN, ETC.	18	BREAKFAST	5:00 A.M.	ANY MAIL ON YOUR UNIT TODAY?		(IF SO REPORT ON FORM 83 WILL BE ATTACHED TO THIS REPORT)
		"	IRRIGATORS		DINNER	12:15 P.M.	RAIN & MAIL 5/27 AT		DO YOU NEED MORE HELP? WHAT KIND?
		"	OTHERS	5	SUPPER	7:45 P.M.	6 PM NOT MUCH		SIGNED Lee Cothren
TOTAL ACRES IN UNIT		"	TOTAL	45			DAMAGE		MANAGER

FIG. 13 FARM MANAGER'S DAILY REPORT

machining replacement parts from rough castings, by making up interchangeable tractor bearings, by providing bushings for valve seats that may be replaced in the field, and by developing methods of using scrap parts such as tractor axles, which are upset and turned down into valves. Farm machinery gets rough service and its life may be increased by strengthening it before it goes into the field. Campbell accordingly trusses and stiffens his machines, and practically rebuilds wooden parts. In all these ways he estimates his shop with its skilled mechanics saves him $2000 a month.

ORGANIZATION

The organization which the Campbell Farming Corporation employs is relatively simple. An operation manager is in charge in the field. There is a farm manager in charge of each of the seven farms who is responsible to the operation manager for the economical operation of his unit. His daily report, reproduced in Fig. 13, brings out all the important facts regarding his day's work. Each farm has its own quota of men, machinery, spare parts, and repair trucks for emergency repairs, and is camped and provisioned as a unit. The field operations of plowing, seeding, etc. are under the supervision of separate foremen who report to the farm manager.

HAULING GRAIN FROM THE FIELD

On a 95,000-acre farm, the hauling of the grain from the field to the shipping point offers an excellent opportunity for engineering analysis. The wagon train shown in Fig. 14 cut the cost from one cent per bushel per mile to one-quarter cent per bushel per mile. With it two men transport 2400 bushels weighing 72 tons at a speed of three miles per hour. A further cut to one-eighth cent is expected from a new scheme using a heavy truck with four rear driving wheels drawing two trailers and handling 1000 bushels or 30 tons at from ten to twelve miles per hour.

DOES IT PAY?

Does large-scale farming pay? Many farmers not familiar with machinery are skeptical. However, here are some interesting figures. With an investment in machinery of $10 per acre in crop, the labor cost per acre for plowing is 27 cents; for seeding, 7 cents; and for harvesting and threshing, 40 cents. The total operating costs for this farm per year, including labor, operating expense, and overhead, will average about $8 per acre. The average yield for wheat in dry farming of this kind may be about 12.5 bushels per acre and for flax about 7 bushels. A simple computation inserting the prices paid for wheat and flax at the elevator tells the story.

FIG. 14 TRAIN OF GRAIN WAGONS FOR HAULING FROM FIELD TO SHIPPING POINT
(2400 bushels weighing 72 tons moved at the rate of 3 miles per hour.)

A.C.S. Nitrogen Symposium

THE economic, military, and industrial significance of nitrogen was brought out at the Nitrogen Symposium of the American Chemical Society, held at Swampscott, Mass., during the week of September 10. Williams Haynes, of New York, who presided at the symposium, pointed out that farm relief is largely bound up in nitrogen, which, being the most expensive element that enters into fertilizers, has an important bearing upon farm costs and the future of American agriculture.

Speaking at the same symposium H. R. Bates, vice-president of the International Agricultural Corporation, Atlanta, Ga., predicted that the world's wealth in future ages would be measured in terms of its nitrogen production instead of its gold.

About thirty years ago, he said, the famous British scientist, Sir William Crookes, had startled the world by stating that unless we took advantage of the inexhaustible supply of nitrogen in the air, to supplement the Chilean nitrate, we should eventually face starvation. This was 125 years after the discovery of nitrogen. Little did he dream of the outcome of his prophecy.

There was hardly a problem in any branch of agriculture or industrial chemistry, he continued, that did not at some point require the consideration of nitrogen.

He pointed out that the function of the fertilizer industry was to provide balanced fertilizers, compounded with due regard to crop requirements, soil, and climatic conditions. For 6,250,000 farms covering 924 million acres there existed, he said, 675 fertilizer factories.

The estimated loss of nitrogen from lands under cultivation in the United States and not replaced by manure, leguminous crops, atmospheric precipitation, and commercial fertilizer he placed at between 3 and 4 billion tons, and to replace this there would be required between 15 and 20 billion tons of sulphate of ammonia. The fact that the soil needed nitrogen replacement was evidence that the nitrogen industry was fundamentally sound.

That America must build its own nitrogen plants was brought out by Jasper E. Crane, president of Lazote, Inc., Wilmington, Del., in discussing "The New Place of Nitrogen in Chemical Economics" before the nitrogen symposium.

Cheap nitrogen was as important to the farmer as cheap power was to the manufacturer, he said, and permitting greater crops to be grown on the same amount of land, it became a labor-saving factor of great importance.

Styling the nitrogen industry as being of first-rate commercial importance, Mr. Crane showed how the nitrate of soda trade was the outstanding feature of the economic situation of Chile, and how the receipts from by-product ammonia played an important role in the coke industry of the great industrial nations. Germany's great synthetic-nitrogen industry, he said had been a leading factor in her financial rehabilitation after the war. Thus nations aimed at becoming self-contained with respect to nitrogen; the instincts of self-preservation both as regards self-defense and the food supply prompting that desire.

These conditions, however, were bringing into the industry nitrogen projects which were unsound. He cited the instance of a plant large enough for military nitrogen requirements of a country but too small for economical production and for lending any contribution to the needs of agriculture. Bolstering up such a project by government subsidy wasted public funds and prejudiced private enterprises, he said. Continuing in the same vein, Mr. Crane said:

"Indeed, in considering nitrogen economics, one is struck by the many uneconomic things that are being attempted. Nitrogen fixation has become the fashion. Everybody is doing it. Many plants have been erected which are too small or improperly located with respect to raw materials or consuming markets to survive the coming competition.

"Another feature of the 'uneconomics' of the industry is the lack of accurate statistics, particularly abroad. Accurate statistics are the foundation of sound economics; we must know what has been done in the past and what is going on today, before we can look ahead intelligently.

"After all, the nitrogen industry is comparatively new, and it is all the more important, therefore, to get our basic facts right, and not depend on premises which are unsound or hopes that may prove false.

"The persistent idea of fixing atmospheric nitrogen at Muscle Shoals is an economic fallacy of the worst kind. The old and out-of-date cyanamid plant there could not compete with present processes and plants.

"The synthetic-ammonia plant built in 1918 was not successful, and very large amounts of capital would be required to erect a modern synthetic-ammonia plant in a location which is completely unsuited for the synthetic-ammonia industry, which requires cheap fuel and a situation near to consuming markets.

"Cheap fertilizer would not be manufactured at Muscle Shoals, and instead of conferring a benefit on the farmer, an attempt to manufacture there would hurt his interest, by discouraging private enterprise, which is pushing forward so fast in solving the nitrogen problem for America."

Other speakers at the symposium and their topics included:

Dr. Walter S. Landis, New York, "The International Nitrogen Problem;" E. M. Allen, President of the Mathieson Alkali Works, New York, "Synthetic Ammonia;" Charles J. Ramsburg, Vice-President of the Koppers Co., Pittsburgh, Pa., "By-Product Nitrogen."

THE LATEST DEVELOPMENT IN POWER-FARMING MACHINERY, THE WINDROW HARVESTER

Power in Agriculture

BY E. A. STEWART,[1] ST. PAUL, MINN.

THE use of mechanical power in agriculture is a modern idea. It is so modern, in fact, that still more than two-thirds of the world's total food supply is secured by man power only, and less than 5 per cent of the world's food supply is produced by means which employ mechanical power. It is a striking fact that the world's oldest industry, civilization's most fundamental occupation, should be the least developed of any industry from the standpoint of mechanical power. However, this can be readily explained. The production units are widely scattered; the workers have inherited habits of work through scores of generations; and until the present century agriculture has never had engineering principles and practices applied to its production efforts.

The present generation little realizes that primitive agriculture, with its crooked stick for a plow and a broken branch for a harrow, is only a few generations back of us in this marvelous machine-made country and that primitive agricultural conditions still exist in large areas of the world. Countless millions of the world's population must still produce their food by hand labor.

It has been natural of course to supplant and to supplement man power with animal power from the earliest days of the domesticated animal. Beasts of burden have been used by nearly every human race for transportation and for tillage purposes. Even as early as 3000 B.C., animals were used in Mesopotamia and Egypt for even other purposes than the two mentioned. Pumping water for irrigation and treading out grain on the threshing floor were two early uses of animal power.

Progress in agriculture has been slow, and civilization cannot do more than keep pace with its agriculture. Centuries were required for the crooked-stick plow to change to a shaped wooden plow, and then later to the wooden plow shod with iron. Iron-shod plows were in use in Israel as early as 1100 B.C. Thus, 2000 years intervened from the crooked stick to an iron-shod plow. Even with this development, and only inadequately applied animal power to operate such plows, the hands of civilization were still tied to the task of food production.

One of the greatest marvels of past history is how the Greeks and Romans constructed their wonderful pieces of art and architecture in the early centuries of the Christian era and how the peoples of western Europe constructed their wonderful cathedrals and other structures at a time when grain was cut with the sickle and threshed with the flail. Their conservation of time and food was a wonderful accomplishment compared to our waste of labor and food products, but their lives of drudgery from dawn to dark and their periods of starvation and pestilence furnish a sordid comparison to our present conditions, with many hours of play and recreation, short hours of work, and plentiful food supplies. With the necessity for 90 per cent of the population to engage in the production of food and shelter, the medieval peoples could never have left such monuments of art to their civilization by working on union hours. These monuments are really monuments to their lives of drudgery, self-denial, and food conservation.

CENTURIES PASSED AS THE PLOW DEVELOPED

It required more than another 2000 years to change the shaped wooden plow shod with iron into a plow with a curved moldboard, and into a plow that really turned over the dirt instead of merely stirring the soil. About 1700 A.D., the Dutch people perfected a moldboard plow, and they exported it to England in 1730. De-

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velopments then began to come rapidly. Within another half-century the cast-iron share made its appearance, and by 1803 the first chilled plows were put on the market. In 1833 John Lane and in 1837 John Deere made the two first steel plows. It was not until about 1850, or less than 80 years ago, that steel plows were put on the market.

The development in plows typifies agricultural development. The plow and the spiked-tooth harrow were our only agricultural implements previous to 1800, the year of the author's grandfather's birth. Crude types of grain drills, mowing machines, reapers, corn planters, dump rakes, corn shellers, and threshing machines were developed between 1800 and 1850, with only a few being in use when his father was born in 1841.

The year 1850 marks the beginning of modern agricultural

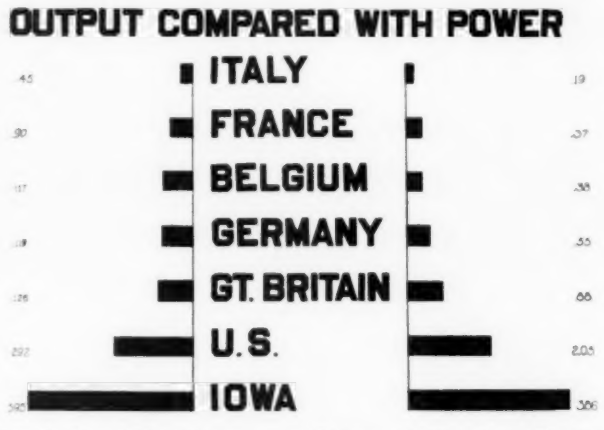

FIG. 1 THE CLOSE CORRELATION BETWEEN OUTPUT PER WORKER AND POWER USED PER WORKER IN AGRICULTURE
(Figures at the left show relative production per farm worker (world's average is 100), while on the right is shown the amount of horsepower used per farm worker.)

machinery. During the next three decades the self-binder using twine, the modern mower, the cylinder grain thresher, the hoe-type grain drills, cultivators, and other tools were developed, and many were in use at the time of the author's birth in 1885. Animal power was still used almost entirely. A few windmills and steam engines, almost negligible in number, were in use. The large variety of agricultural tools now in use, with specialized equipment for each kind of crop and for use with mechanical power, such as corn planters, potato diggers, corn harvesters, gang plows, hayloaders, combine harvesters, etc., are a development of the present generation; and modern power farming, with gas tractors, trucks, electricity, etc., is now only a baby in swaddling clothes, an infant of fifteen years in the lap of old Mother Agriculture, now thousands of years of age.

During the infantile and juvenile days of machine farming, up to 1875, the new member of the agricultural family had a precarious existence. Cyrus McCormick was hooted and jeered by the crowd of curious onlookers when he demonstrated his reaper; reapers and threshing machines were burned by laborers who were afraid of losing their jobs to the new machine-farming baby. City dwellers, even though they found food scarce and had bread riots and had to import foodstuffs, could not see the importance and the value to civilization of machine farming. Financial houses did not encourage or assist the manufacture of farm machinery, nor did they assist farmers in securing such machinery.

After many years of struggle, the whole civilized world awoke to the fact that the release of workers from the production of foods and raw materials, by the application of machinery, was making it possible for such workers to produce those extras which make the workingman's house a home and make life worth living. The automobile, the fine modern homes, the radio, our transportation methods, parks, museums, etc., have been builded by the labor that machinery has released from the production of food and clothing. Even with such machinery as was available in 1850, approximately one out of five people in the United States was engaged in agriculture, while by 1920 not even one out of ten was so engaged, and yet this small number of farm workers produced a very large exportable surplus of foodstuffs.

Machine-farming developments from 1850 to 1920 have released approximately 27,000,000 workers from agriculture. Picture the undeveloped state of our cities, industries, transportation, and above all the entire absence of our modern sanitary and labor-freeing homes if we were still required to produce our agricultural crops as we did one hundred years ago. It takes but little imagination to picture our now beautiful country with its marvelous beautiful cities, as a peasant country ground down under long hours of toil, poorly educated people, faced periodically with famine and pestilence, with simple labor-killing homes for our families to live in if farming were now carried on as it was in 1830.

POWER FARMING NOW IN ITS INFANCY

History repeats itself. The baby, "power farming," is now being laughed at by many people, and they see it in the same light as they saw the beginnings of machine farming. Conscientious objectors in all walks of life say that "it can't be done." Many people have been and are still opposed to the use of mechanical power to replace animal power in agriculture. Financial interests have done but little to encourage the farmer in using power. "Power farming" is still so much of an infant that great

FIG. 2 THE COMBINE (HARVESTER-THRESHER), A MODERN POWER-FARMING MACHINE THAT REDUCES COST OF PRODUCTION

masses of people, including farmers and even agricultural leaders, have not grasped the importance of this new member of the farming family. What machine farming has done for this country in the last century will be more than duplicated by power farming during the twentieth century.

While our population in 1950 may be six times as great as in 1850, yet it is conceivable and probable that the decrease in number of farm workers which started to take place in 1910 will continue, and by 1950 no more farm workers will be required to supply food for a population of 150,000,000 than were required in 1850 for a population of 25,000,000. What does it mean to a country to have millions of its workers freed from agricultural pursuits? It means better homes, higher standards of living, lessened hours of labor, better health, and more happiness.

What are some of the things that have already been accom-

plished by the application of power to farming that lead us to predict what power farming can do? One very interesting result is shown by Fig. 1. This chart reveals the very close correlation between volume of production per worker and the equivalent power per worker. A small amount of power per worker, as is available in countries like Italy and France, gives small returns per worker. Data for our own states show a striking similarity to these data for different countries. Nebraska, with nearly six times the power available per farm worker there is in Alabama, has an output per worker over eight times as much.

The total power requirements of agriculture in the United States are staggering. In 1924 the estimated primary horsepower on farms was 47,420,000 hp., out of which animal power was less than 20,000,000 hp., while in 1900 animal power constituted more than 80 per cent of the total farm power. In a brief period of 24 years mechanical power on farms has increased nearly eightfold and is now over 50 per cent greater than the animal power. Contrast the total horsepower just stated with that given in the last United States census as 29,504,792 hp. for all manufacturing industries. This is the status of our baby, "power farming," now barely 15 years of age. What a giant he is likely to be by 1950!

Power intelligently applied to farming practices offers a tremendous opportunity for decreasing labor costs and the total costs of production of farm products. The use of a grain elevator, a hopper-type feed grinder driven by an electric motor, and properly arranged feed bins, enabled one farmer to change a 6-hour job into a 14-minute job. In another case, a farmer by using a milking machine reduced his total daily milking time from 10 hours to 6 hours and 10 minutes. Such applications as these on

FIG. 3 SPRAYING OR DUSTING WITH A POWER-DRIVEN MACHINE PRODUCES EFFECTIVE RESULTS AT REDUCED LABOR COST

a widespread scale can revolutionize agriculture in a few years. The average cost per horsepower-hour of all power used in the United States in 1924 was 19 cents. What other industry could survive with such high power costs?

Since it has been shown that electric power can be secured on farms where used in large quantities at 4 cents per horsepower-hour and even below that, electric power will assist the farmer materially in reducing his power costs. Electricity for agriculture is the infant member of the "power farming" group and is just getting started. The number of farms having "high-line" electric service has approximately doubled since the first experimental work in the world on rural electrification was started at Red Wing, Minn., in 1923. Over 300,000 farms in the United States had electric high-line service at the beginning of 1928. This number of electrified farms will probably more than double again in the next four years.

LARGE MACHINE UNITS ARE RAPIDLY COMING

The use of large farm-machine units, driven by mechanical power, has been increasing very rapidly during the past two or three years. A recent letter from the Department of Commerce states: "The large increases in the output of combines (harvester-threshers) and tractors in 1927 over previous years are indications of the trend of agriculture toward the abandonment of antiquated farm machinery and the adoption of more modern, labor-saving devices. The number of combines manufactured increased from 5131 in 1925 to 11,760 in 1926 and to 18,307 in 1927, and the output of tractors increased from 167,553 in 1925 to 181,995 in 1926 and to 200,504 in 1927."

FIG. 4 ENSILAGE CUTTING IS ONE OF MANY JOBS SATISFACTORILY DONE BY ELECTRICITY ON THE MODERN FARM

If the present total crops of the United States could be produced under conditions where the average man-hours per unit of production were even twice those of efficient production with mechanical power, less than one-half of our agricultural workers would be required in agriculture. In some states as much as 42 hours yearly is required per acre of grain raised, while with power farming and combines this can be reduced to less than 5 hours yearly. Corn in some states requires over 60 man-hours yearly per acre, while power-farming methods can reduce this to less than 5 hours yearly per acre. Some one has made a summary of the labor involved in corn production. With one-man power, it requires about 300 hours of man labor per acre of corn; whereas with a one-horse method, it requires about 100 hours of man labor; with two horses, 40 hours; with 4 horses, 15 hours; and with 5 horses only about 9 hours. With the latest type of power-driven equipment, a heavy corn crop, far above the average, was produced at Iowa State College with 3.83 hours of man labor per acre.

When the average number of hours per acre of corn raised in a state like Iowa, with all of its modern machinery, is more than five times the average on some farms where power-farming methods are used intelligently, it points to the fact that farming conducted under wise direction and with the use of mechanical power can reduce the cost of production to such a point that farming can be made a very lucrative business. Mr. Campbell, the "wheat king of America," stated recently that he did not know of a single industry where a young man with proper engineering training could make bigger returns than by applying engineering to agriculture on a large scale properly financed. Mr. Campbell, by applying engineering to wheat farming, produces wheat at

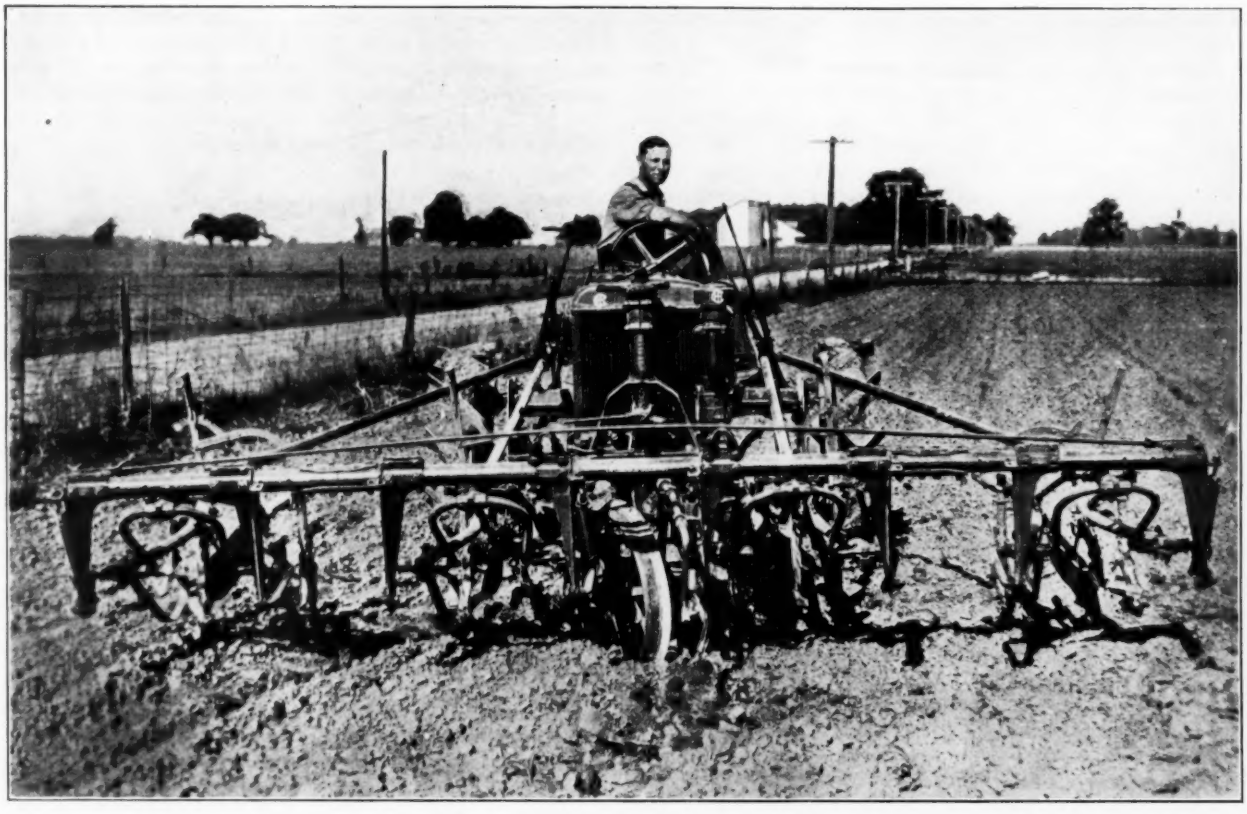

Fig. 5 Cultivating Corn With a Power-Driven Unit Is a Different Job From Following the One-Horse Cultivator

Fig. 6 The Tractor and One Man Can Prepare a Large Acreage in One Day With This Large-Scale Equipment

about one-third of the average cost of production in the wheat belt.

Power in agriculture has many distinctive features. Its use is seasonal, much more so than for city industries. The load factor is very low. Data for 1924 show that only 16,000,000,000 hp-hr. were developed by 47,420,000 hp., giving a load factor of less than 4 per cent. Even if we were to consider just the working day of 8 hours, we have a load factor for working hours of only 12 per cent.

Farmers have not realized what fixed charges and overhead charges are. When agriculture is properly managed from an engineering standpoint, this load factor can be doubled and trebled and fixed charges for power reduced accordingly. Power and labor costs are the most important factors in the cost of agricultural products. Power and labor costs for the average farm amount to about 60 per cent of the cost of production, other fixed costs on land, etc., amount to about 20 per cent, and other operating costs, such as seeds, fertilizer, etc., to about 20 per cent. In some crops, power and labor costs amount to as much as 90 per cent of the cost of production. Does it not seem logical to attack the farm-relief problem at the point where there is the greatest opportunity for effecting a change?

Helping the Farmer by Cutting Costs

If power and labor costs can be reduced by 25 per cent, we shall not need to worry about helping agriculture with a revised tariff or a McNary-Haugen bill. These costs have been reduced more than 75 per cent on many farms. By the use of power we can reduce the man-hours in agriculture so that it will not take $2^1/_4$ hours of a farmer's time to produce the same wealth as his city brother produces in 1 hr.

With this Utopia of power farming that the author has painted for you in mind, you may expect to see agriculture lifted from its slough of despondency and stabilized, and to see our farm business advancing with strides comparable to the past performance of the automobile industry. This, however, we cannot predict. Applying power to farming is a difficult task. A man to do it must be a farmer in every sense of the word, a business executive, and an engineer. Farms with capital investments in many cases in excess of $50,000 are going to be necessary for proper success. The Red Wing farms on the experimental electric line have an average investment in excess of $30,000, and these are not average farms of the future.

What percentage of our farmers do you think have developed sufficient business and financial ability so that you would trust them to run a $50,000 engineering and scientific enterprise for you? Is this condition, however, any different than in other infant industries? How many power-company executives did we have in this country capable of handling a $1,000,000 enterprise in 1890? How many do we have today? Where did we get them?

In the same way, men in agriculture must be developed to manage this new type of farming which requires an engineering executive.

Until such farming executives are developed, small-time actors will try to play the big time and fail. Their failures will be thrown to the sky and paraded on high by the "I told you so" opponents of power farming.

In spite of such failures and such opposition, real "big time" engineering farming executives are developing here and there in the United States. Manufacturers and inventors are daily developing new and more efficient equipment for power farming, public utilities are spreading their rural electric lines like cobwebs over the country, and power farming is marching on in a way similar of the advance of power in other industries. With the agricultural engineer now getting out of his rompers and with the interest of business executives in farming, if Congress delays agricultural relief through many more sessions we hope that more efficient production will put agriculture where it does not need relief, an apparently safer thing than relief by artificial controls and barriers set up by legislative enactment. Power will do for agriculture what it has done for other industries.

Discussion

SUPPLEMENTING his paper, Professor Stewart said that with all the new machinery developing so rapidly for the use of power, we could anticipate in the very near future that we were going to have more problems to solve in connection with agriculture than the politicians were cognizant of at the present time. Surpluses of both farm labor and produce were going to be real problems in the future. We should have a very difficult surplus problem to handle because of the fact the minute wheat or corn farming was made more profitable, up would go the acreage. Anything done to make farming more profitable would give us a very big crop surplus to handle. He was of the opinion that after all the best solution for agricultural relief was the application of power to farming, and the application of business management in farming and in this use of power.

Many people in the past had said that the tractor had driven farmers into bankruptcy, and that if they had not bought so many tractors there would not have been so many bank failures and so many people losing their farms. That might be so, but it was no condemnation of power in farming. The use of the tractor simply demonstrated the ability of the average farmer to handle an engineering business proposition. Where would we get the men to do it? Just where the electrical industry got its men to handle thirty-, forty-, and fifty-million-dollar enterprises today—they would have to be developed in the agricultural industry.

Arnold P. Yerkes[2] said that we needed to get out of the American farmer's head the notion that his class suffered because men in other industries prospered. He suffered when competition got keen in his own industry, not when others were prospering. When the city industries suffered financially the American farmer suffered financially, too, because he had a poorer market.

Production on a large scale was what was needed. That meant a large amount of power per worker. Both quantity and cost must be considered in farming as in any other business—they were both important in the cost of production. This relationship could perhaps best be shown by comparing results and the cost of a single operation where an adequate amount of power was employed. The first step in raising a crop was turning over the soil and getting a clean seed bed. The earliest method of doing this was man power, applied to a sharp stick, bone, or shell. Taking man labor at $4 a day, it would cost $160 per acre to prepare a seed bed this way, and a man would have his hands full to take care of $^1/_2$ acre. With a spade he could do $^1/_{10}$ of an acre a day at a cost of $40, and could cover two acres in a year. With one horse he could plow an acre a day. Counting overhead, interest, depreciation, and labor, it would cost $6.50 an acre, and he could take care of 20 acres. With two horses he could plow four acres a day, at $3 an acre, including overhead, and could handle 80 acres of crop a year. Put him on a 15–30 tractor and the cost would go down to $1.25, and he could farm 250 acres in a year.

Thirty per cent of the farmers in America raised 80 per cent of the crops and livestock. If we could get American farmers as a class educated to use the power equipment which we had today and the machinery to go with it as efficiently as the best 10 per cent and release the remainder to other industries, a lot would be better off.

[2] Editor, *Tractor Farming*, Chicago, Ill.

Mechanization of Agriculture

Some Variables Which Influence Design of Farm Machines—Important Economic Problems—Recent Developments—Present and Future Trends

By L. J. FLETCHER,[1] PEORIA, ILL.

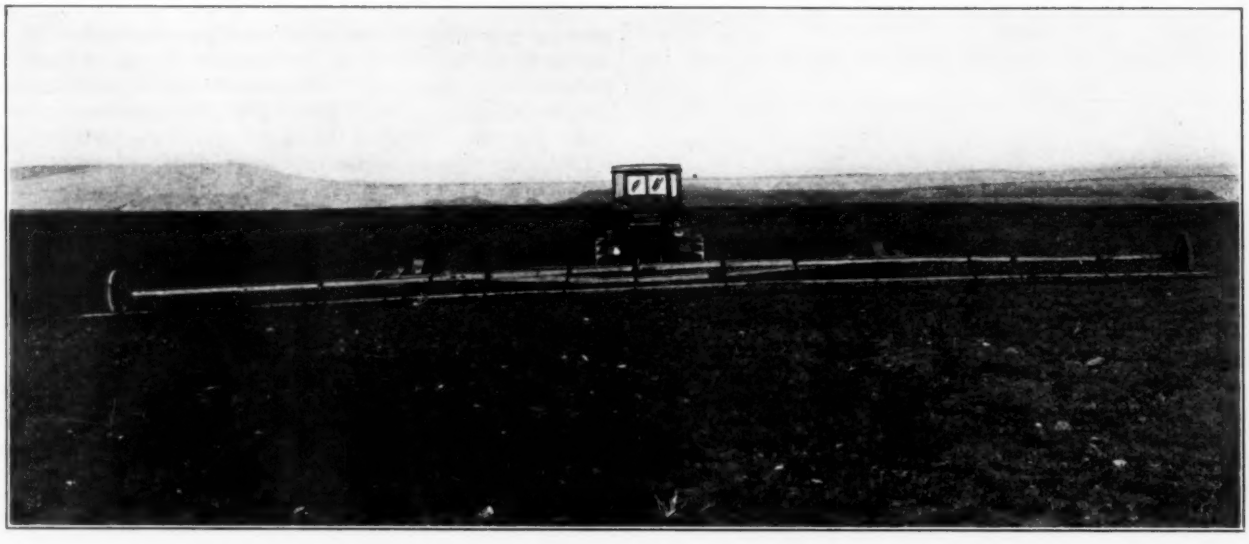

FIG. 1 CULTIVATING SPRING WHEAT WITH A 70-FT. SPIKE-TOOTH HARROW
(Two of these 60-hp. tractors do all the field work on a 3000-acre wheat farm at Fife, Mont. Note the enclosed cab to protect the driver and the lights provided for night operation.)

WHEN engineers consider the problem to be solved by a farm machine, they think generally of a material of certain characteristics to be moved from one place to another or altered physically. This paper, however, will not attempt to go into the various methods employed by our modern farm machines to accomplish their tasks, but rather it will be devoted mostly to the factors sometimes overlooked when considering the engineering of agriculture.

VARIED CONDITIONS IMPOSED BY AGRICULTURE

First, the variables encountered in agriculture influence, to a marked degree, the design of farm machinery. For example, the soil is far from a constant. The draft of a plow may be six times as much in one soil as another. Again, the varying moisture content of the soil may determine whether it may be worked best with one type of tool or another. The abrasive qualities of the soil encountered very materially affect such matters as steel treatments, materials, and enclosures provided to keep the dust out of the bearings. Loose and fast stones in many eastern farming sections furnish a real problem to the designer of tillage machinery. The ability of the soil to provide traction varies greatly and makes necessary extensive studies of lug equipment for wheels, as well as wheel sizes and widths. It was the soft, yielding character of the peat and muck soils of the San Joaquin Delta which first prompted Benjamin Holt to develop the "Caterpillar" tractor.

Variables in topography also present problems to the farm-machine designer. Combined harvesters to work satisfactorily on the steep hillsides must be provided with leveling devices; plows and other tillage tools are developed so as to be reversible, and special provision must be made to insure the stability of machines on hillsides.

However, the variables of soil and topography may be considered constants in the light of the changes imposed by the weather. Not only will rain cause the soil to vary in many of its characteristics but it will also materially alter the crop as it reacts to the work of harvesting or threshing machinery. Temperature and humidity variables also have their effect on machines. Variable winds have sometimes been the cause of failures or partial failures of such machines as broadcast seeders, spraying and dusting machinery, hay-drying equipment, and threshing machinery.

However, in considering the profit derived from agriculture the greatest variable of all is the technical and managerial ability of the farm operator. This is a subject concerning which much could be said. In studies made of profits from farming, numerous cases are discovered where adjacent farms with similar physical conditions have paid one owner a profit while his neighbor suffered a loss, the entire difference being the ability of the operator.

There is another variable in agriculture which may now present a problem, but it also offers one of the most unusual solutions ever offered to any industry. This is the variable of the plant or crop itself. Due largely to the difference in rainfall, wheat grows with a short straw in many western states, while in the middle-western and eastern states it produces a rank, heavy straw. On many western farms the straw is a nuisance and its only function is to lift the head of the grain high enough above the ground so that the cutter bar can get underneath. In the East the grain straw is of economic value and it is desirable to save it for feed and bedding purposes. This is a variable which

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the manufacturer of combined harvesters must take into consideration. The same may be said of cotton, which in western Texas is planted in the bottom of the lister furrow so as to get all the water available, while in the Mississippi delta it is planted on top of a bed or ridge so as to be out of the water. The western Texas cotton grows but a foot or two in height and the bolls may be left on the stem and harvested all at one time in the fall, while in the cotton sections to the east, the plant grows to considerable height and the cotton must be picked as soon as it matures.

The unusual solution just mentioned has to do with the

FIG. 2 PLANTING FIFTY ACRES OF PEANUTS A DAY WITH A FIVE-ROW PLANTER NEAR LEESBURG, GA.
(Two men are here producing a 500-acre peanut crop.)

vast possibilities which the plant breeder can exercise in changing the physical characteristics of the plant so as to enable a more effective use of machinery. For example, there is the development of yolo, a type of grain sorghum grown in California. The varieties of milo and Egyptian corn available up to 1920 did not produce their grain in a fashion uniform enough for machine harvesting. By a process of hybridization and selection there was developed a grain which grew to a uniform height and held its head erect. This made possible the use of a wide variety of machines in the harvesting of the crop. In other words, in agriculture it may be possible to change the characteristics of the plant material worked on to accommodate it to the machine. This may be compared to the possibility of changing the character of steel so that it will be plastic while cold and yet be capable of hardening without heat.

ECONOMIC FACTORS INFLUENCING FARM MACHINERY

Economic considerations enter very strongly into the design of farm equipment. For example, the load factor, that is, the percentage of annual full-load use of all power units employed on farms in the United States, is about 4½ per cent.[2] Manufacturing industries enjoy a load factor of over 14 per cent. Were this efficiency possible in agriculture, the present fifty million primary horsepower could be reduced to less than twenty million. Some well-managed electric utilities are now securing load factors of over 50 to 60 per cent.

One of the big problems in agriculture, which has been largely complicated by the emphasis placed on the value of crop diversification, is the large variety of machines needed to produce efficiently several crops on one farm and the relatively small amount of annual use of each machine. For example, on the average corn-belt farm, the corn binder is used less than fifty hours a year; and the grain binder, which was developed to displace the tremendous amounts of hand labor involved in cutting and binding grain, is often used but four or five days a year. It is therefore easy to see why farm machines are not built with the best type of bearings or with materials which will resist unusual shocks and wear. Well-meaning authors have written articles which point out that a lathe in a machine shop will operate with but little mechanical attention for periods of five to ten thousand hours, while some farm machines will be worn out in five hundred hours. At that, the farm machine very likely serves more years than the lathe. The raising of the load factor of its equipment is one of the real problems facing agriculture. The large farm may be the solution.

Another economic consideration is that of quality in farm products. For example, hay of the highest quality may sell for $10 per ton more than hay of the next lower grade. Many people, in studying the handling of hay, consider it just so much material to be moved or lifted. However, a close study of this problem will show that minor changes in the methods employed and the time of their employment are vital factors in producing quality products. There may be an even greater premium placed on quality as a greater industrial utilization of farm products develops.

An economic factor which enters into the quality of the construction of the farm machine is the value of time, or, in other words, the necessity for performing certain operations without delays. For example, the spraying of fruit trees for the control of certain plant diseases or animal pests will frequently be of no value if delayed for as much as one or two days. Hence the farmer will be more justified in paying for high-quality construction in a spraying machine than in some other piece of

FIG. 3 PLANTING SPINACH ON THE TAGUS RANCH IN THE SAN JOAQUIN VALLEY, CALIF.
(Three operations are being accomplished; furrowing with a lister; leveling and shaping the bed with a specially constructed float which smooths and shapes the sides of the furrows; and planting six rows at the rate of 20 acres a day.)

equipment where the timeliness of the operation is of much less importance.

SOME RECENT DEVELOPMENTS IN FARM MACHINERY

It is not possible in this paper to describe or even to mention all of the recent developments in mechanical farm equipment. In tillage machinery the one-way disk has rapidly covered the wheat belt and is finding new markets in the East. A new type of rotary tiller or soil pulverizer is being perfected and put on the market. The rotary hoe has been revived to meet the cultivating needs of the producer of soy beans and corn. There is a general abandoning of the idea of the mulch to conserve moisture and more attention is now given to weed control, especially in preparing better seed beds and weed eradication immediately after planting while the crop is small.

The control of the corn borer has been due largely to the universal employment of new types of farm machines, such as

[2] Calculated from data in U.S.D.A. Bulletin No. 1348, "An Appraisal of Power Used on Farms in the United States."

wide bottom plows, stubble pulverizers, low-cutting corn binders, and field burners.

Much attention is now being devoted to artificial drying of hay and grain. There are great possibilities in this field for improving the quality of hay and the dependability of the crop, and for extending the hay-producing areas.

The windrowing attachment and the windrow and shock pick-up attachments are recent combined-harvester developments which will allow the use of this great labor-saving machine in practically all grain-growing sections.

The mechanical cotton picker is now being used in the South where, with almost uncanny accuracy, it passes through the cotton rows, removing the ripe cotton from the boll and leaving unharmed the green or unopened bolls, the flowers, and the leaves.

A successful sugar-cane harvester has been the object of the expenditure of much time and money. N. C. Storey, of the Southern Sugar Company, Clewiston, Fla., has recently developed a machine which promises a mechanical solution to this problem of cutting, stripping, and topping cane.

There is also a decided tendency toward the combining of several farm operations into one. This is mainly due to the change from the horse to the tractor, where the tractor has ample power to pull several tillage tools or combine them with planting operations. Plows and harrows are being attached to harvesting machines so as to kill the weeds immediately after the harvest and thus conserve moisture for the next crop. General-purpose tractors designed to plant and cultivate two, three, and four rows at a time are now on the market. Potato diggers are built to dig two rows at a time, their mechanism being operated through a power take-off from the tractor engine. The South is beginning to realize her many natural advantages of soil, moisture, and growing season, and is adopting machine methods of production. Near Leesburg, Ga., a 500-acre field of peanuts has been handled entirely up to harvest by two men and a tractor; the work including the initial tillage, weeding, planting, and cultivating five rows at a time, and later the same equipment will be used to dig the peanuts. Several new methods of harvesting will be tried out. This work is being supervised by J. I. Davis, the county agricultural agent, with headquarters at Albany, Ga.

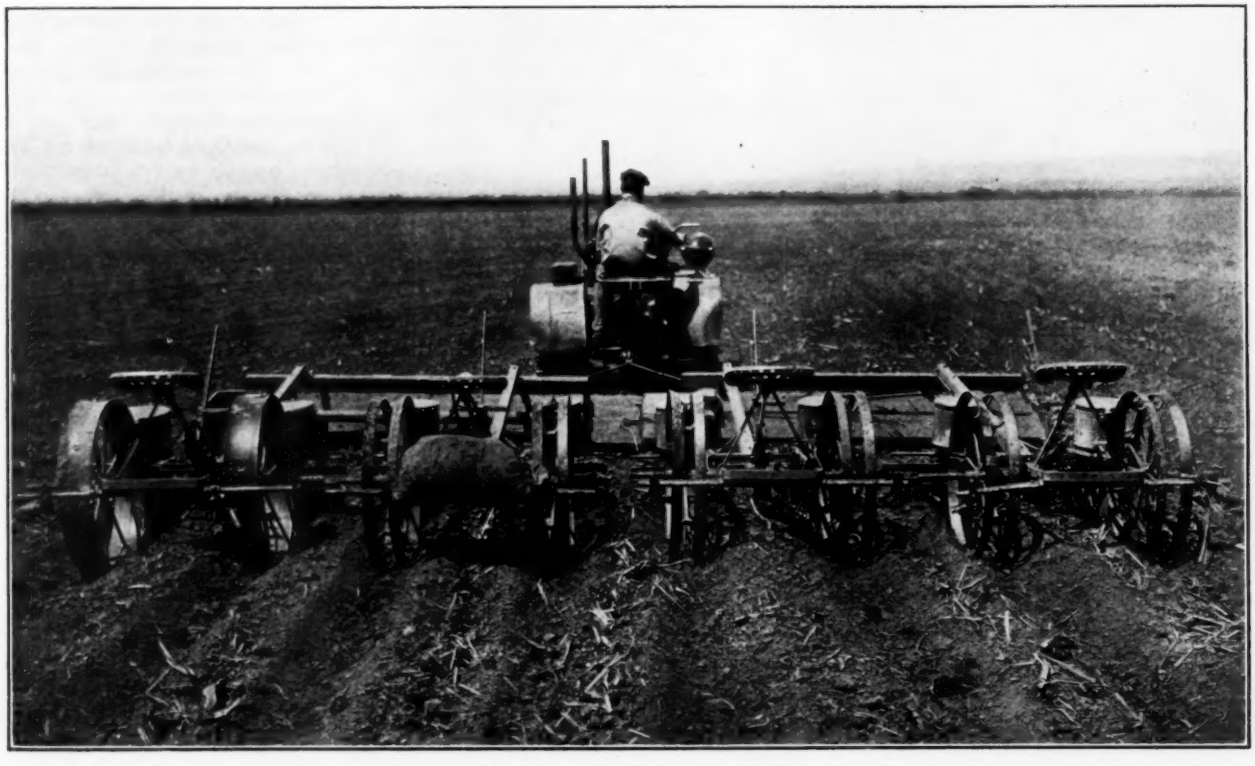

FIG. 4 A 30-HP. TRACTOR AND A COMBINATION OF HEAVY SMOOTHING FLOATS AND 4 TWO-ROW PLANTERS LEVEL THE SEED BED AND PLANT GRAIN SORGHUM AT THE RATE OF 9 ACRES PER HOUR

(The tractor and operator are here replacing 12 horses and 6 men. Lighting equipment doubles the usefulness of the tractor.)

PRESENT TREND OF DEVELOPMENT IN FARM MACHINERY

It is quite evident that until the last few years the motive behind the development of farm machinery was to save labor. In fact, modern farm machinery is usually spoken of as "labor-saving" farm machinery. Tillage tools for use with animals were developed first, thus relieving the early farmer of the task requiring the most in physical exertion. Later, harvesting machinery was developed and, after that, planting machinery. The present trend in farm machinery, however, is somewhat away from the labor-saving factor and is beginning to consider profit-making possibilities. In other words, present machines must answer the question—Does it do the work cheaper for the same quality, or does it produce a better quality at the same cost? As an example of this new method of approach we have potato pickers which are attached behind a digger. Men riding on these pickers remove stones, clods, and other foreign material, while a man riding on the rear of the machine aids in the sacking operation. Here, as in other types of new machines, the man is used in places where judgment is required, while the machine relieves him of transporting himself or the product and removes from him, as far as possible, all unnecessary effort.

Farmers are today trying new methods as never before in the history of agriculture. This is largely due to the combined re-

sult of the educational work conducted so effectively by state and federal agricultural extension workers and the well-directed farm press. The continuous airing of the "farm problem" by politicians is tending also to make the farming industry realize that something should be done, and it is quite evident that it will

FIG. 5 KILLING SMALL WEEDS IN AN IOWA CORNFIELD WITH A TRACTOR AND THREE ROTARY HOES

be largely up to the farmer to do it. The rapid increase in the use of the combined harvester east of the Rockies is an example of the present tendency to adopt new methods quickly. Thirty years ago thousands of eastern wheat farmers knew of the successful use of the combine on the Pacific Coast. The belief that it would not handle the grain produced under more humid conditions, together with the reluctance to change methods prevented, for many years, the introduction of this most profitable machine.

Because of this increased confidence in new methods it is most important that designers of farm machines acquaint themselves with all of the requirements that the machine must meet.

There is need for more basic data on which to base the design of machinery. This is particularly true of tillage machinery. State and federal agricultural experimental stations now have under way many projects, which, when completed, will furnish valuable data and information to the designer of farm machines.

FIG. 6 A 2-TON TRACTOR PULLING A HEAVY ORCHARD-SPRAYING OUTFIT IN A PENNSYLVANIA ORCHARD

(The pump on the spraying outfit is operated by the tractor engine through a power take-off.)

It is always somewhat dangerous to make predictions, particularly in writing, for they have a habit of bobbing up in later years. However, there are certain conditions existing today which are bound to influence the character of farming and thus the character of mechanical farm equipment.

The complication of the problems facing agriculture is increasing very rapidly. It is quite evident that trained management pays in agriculture and that there is now need for the specialist in crop and animal production, disease control, management of power and machinery, and marketing.

The agricultural colleges are adding annually to this group of trained men; but the average farm of today does not offer a sufficient inducement to these graduates as compared to other outlets for their abilities.

The immigration policy, which keeps out of the country large numbers of people who would be content to use hand equipment in agricultural production, is making necessary the use of machines for multiplying the effort of one man.

This country does not labor under a caste or peonage system in which farm laborers are considered inferior to the professional man or manufacturer. Here agriculture is a respected occupation, and there is nothing to prevent its developing further as a great industry with able management and well-paid workers.

Our tariff policy is clearly one of protecting our own industries, and it seems very probable that some way will be found to apply this principle to agricultural production.

One of the present problems of agriculture is that of paying too much for credit. In general, money at comparatively low interest rates is available in this country for safe investments. If the present high credit charges are justified, how can the risk be removed so that agriculture may enjoy low money rates comparable to other industries?

There is also being gradually developed here and there the partial manufacturing of agricultural products on the farm. In some ways this will help utilize existing power and machinery equipment and thus raise the load factor. It will offer much more continuous employment for labor and thus tend to do away with the seasonal nature of some agricultural employment. One of the major problems in connection with manufacturing on the farm is the matter of standardization of the product so

that it may be marketed or utilized by urban industries for completing the manufacturing process.

Studies made recently tend to show that in spite of a decreasing farm population there is a considerable increase in the amount of crops produced; thus it would seem that by producing a surplus and thus lowering prices, agriculture is suffering from its own efficiency.

A peculiar paradox existing today is that as the nation becomes more prosperous less food is actually consumed. The machine has relieved us from being the producers of energy; we are now the directors of power; it takes less meat and potatoes to handle the throttle than the pickax and shovel.

One of the bright spots in this situation, however, is the rapid tendency to develop "non-stomach" uses for agricultural products; i.e., such materials as wallboard from sugar-cane bagasse or corn stalks; rayon from cellulose derived from a wide variety of plant materials; oils from soy beans, used in the manufacture of paints and varnishes. In the experimental laboratory a large number of synthetic products have been made from corn cobs and corn

FIG. 8 "HOLT" COMBINE EQUIPPED WITH SHOCK PICK-UP AND FEEDER ATTACHMENT, COMPLETING THE THRESHING JOB

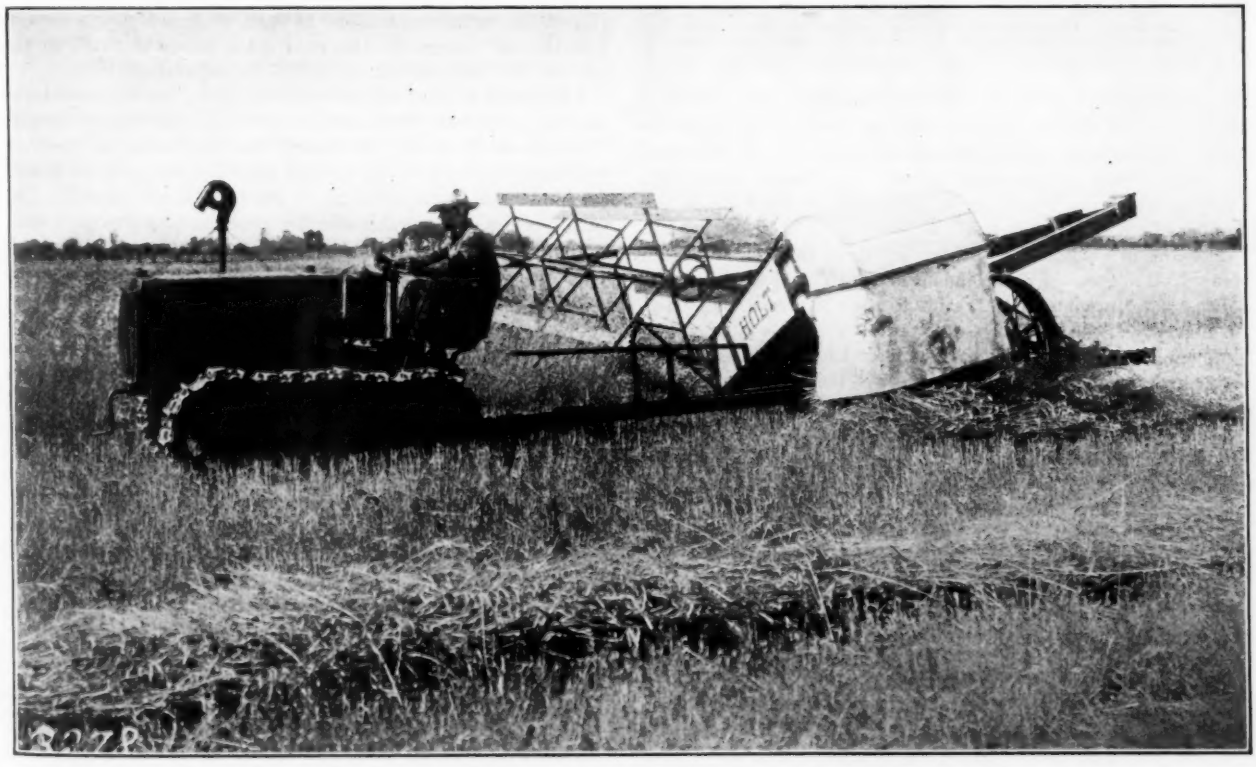

FIG. 7 THE WINDROW ATTACHMENT, A RECENT DEVELOPMENT IN GRAIN HARVESTING

(Where the grain or weeds must be cut and dried before separating, or where very large acreages are to be handled, this system is solving the problem. Later a combine equipped with a pick-up feeder attachment will finish the job.)

stalks which tend to point the way toward future economic developments.

Mechanical farm equipment itself has undergone marked changes in recent years. The tractor has become a dependable economical source of energy, and farm machines, well adapted to tractor operation, are increasing in number each year. The tools for a different agriculture are being developed today.

Many people will say that the factors which have been mentioned point the way toward corporation or large farming. However, a study of the census will show that there is also a large increase in the number of very small farms. Many of these are located near cities and are mainly the residences of city workers who desire to live in rural surroundings. Other small farms are used to produce crops which pay a large return for more intensive cultivation. Another reason for these small farms is

FIG. 9 AN EFFICIENT COMBINATION AT WORK NEAR AUBURN, ALA.
(Oats are being cut and bound, cow peas broadcast on the stubble, and then the stubble land plowed with a one-way disk. Two men and a tractor do all this with no delay between crops; saving time and labor.)

the enthusiastic real estate man who secures a parcel of land near a city and divides it up into five- and ten-acre farms, advertising vigorously the advantages of rural life and its attendant freedom. Many of these small farmers have learned differently. There is even now beginning to be evident a lessening in the number of middle-sized farms.

The author's purpose in presenting these factors, which are bound to influence the development of agricultural machinery, is not to prove a prediction, but rather to allow the reader to predict for himself. If the large farm does prove to be the way out, then farm machinery will undoubtedly undergo many changes. With better load factors, many machines may be built of higher quality and in larger sizes. Added impetus will be given to the changing of the character of farm crops so they may be more economically handled by machines. It should be possible to determine the relative value of all crops capable of production in the United States on the basis of their use for food, shelter, or clothing for domestic as well as export consumption. Each of these crops could be studied from the standpoint of production by modern American machinery methods. If it were clearly shown that hand cultural methods were absolutely necessary for the production of a certain crop, then why should not this crop be raised by the nation which uses hands rather than heads? We could then exchange for it crops produced here, or go without or produce a synthetic substitute. After all, does not this problem reduce itself to the producing of more units of food, shelter, or clothing at a lower expenditure of labor and money so that an ample profit may be returned to the manufacturer —that is, the farmer?

Discussion

TO THE discussion which followed the presentation of the paper, E. M. Mervine[3] and William Boss[4] contributed. Professor Mervine spoke of the present trend in the development of farm machinery. This, he said, was illustrated by the tiller plow which in one operation did work similar to that accomplished in the four operations of disking, plowing, disking a second time, and pulverizing. The tendency in the past had been to build a machine which was an adaptation of hand- or horse-power methods so it was natural for plowing and disking to have been distinct operations. The combining of the two operations, at the same time cutting down the power requirements of each operation, was very significant, he said.

He pointed out that the horsepower rating of tractors had always indicated that only one-half of the power was available in pulling a field machine. At the same time all of the internal mechanism of the driven machine had been operated from its bull wheel, a method of power transmission quite necessary with the horse-drawn machine but always a source of considerable trouble and inefficiency. The present "power take-off" connection to tractors was one of the signs of the times.

The history of the development of grain harvesting, he said, from the sickle to the present binder and threshing machine, was most interesting. The almost human ability of the binder to go for an entire day without missing the tying of a single grain bundle was to be wondered at. A satisfactory way of describing the operation of this mechanism was to show just how nearly human it was in its operation. Likewise a satisfactory way of indicating the amount of labor saved by the threshing machine was to compare its operation to the same operation as performed by the operator of the flail. After the grain was threshed, he said, the straw racks separated the long straw in much the same manner as the early thresherman raked the long straw from the pile on the barn floor, and just as the grain was formerly thrown into the air to separate the good grain from the chaff, so the modern thresher used the wind blast for separation.

Another illustration of the trend of development in machinery was the acceptance of the combine by the middle-western farmer. The combine illustrated not merely the desire to use labor-saving machinery, but it put this agricultural operation on more nearly the same basis as that of some of the other large industries, i.e., one in which the variable-weather problem was less of a controlling factor. A better illustration of the trend of modern methods to eliminate the variable-weather problem was to be found in the equipment for artificially drying crops.

In conclusion, he said that in the early days the farmer and his local blacksmith built the first machines and were responsible for many of the developments. Now, the manufacturer of farm implements must have a design department thinking beyond the adaptation of hand or horse methods. It must be thinking of industrializing agriculture by methods and machinery that might appear revolutionary, but which in reality were just good up-to-date engineering methods.

Professor Boss, who acted as chairman of the session, said that if the combine could not be used in Minnesota, as some had said, it would probably be necessary to give up raising grain on account of competition with states where the combine could be used. He spoke of the work of the agricultural engineer, whose place on the farm had been demonstrated.

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Progress and Trend in Hydraulic-Power Development

By H. A. HAGEMAN,[1] BOSTON, MASS.

UP TO 1890 water power was used largely in the textile, milling and paper industries. The prime movers consisted of single or multiple runners on both vertical and horizontal shafts, with geared or belted drives to the machinery to be operated. The head developed at the power site was usually less than 100 ft. and the maximum output of a unit rarely exceeded a few thousand horsepower. At about this time the first steps were being taken in the development of machinery for the generation, transmission, and use of electric power, which machinery has made possible the successful and economical distribution of the power and energy from water-power sites to markets many miles distant.

Improvements in Dam Construction

The progress in hydroelectric development has been particularly rapid during the past 25 years. Successful methods have been devised for collecting and analyzing stream-flow data and determining the resulting power and energy. Hydraulic structures are designed and constructed more economically. The detail design of dams and their appurtenances shows marked improvement. Considerable attention has been given to drainage systems for dams to reduce the internal water pressure or uplift on the foundation which results from seepage through or under the structure. The effects of temperature changes within the dam have been investigated with beneficial results. More care is used in preparing construction joints in the attempt to secure the best possible bond between adjacent sections of concrete.

Extensive experiments have also been made with the materials of construction, with the result that concrete, both plain and reinforced, is generally used in dam construction.

In overflow dams the spillway shape throughout its length has been improved by model tests, resulting in greater discharge capacity and the elimination of damaging erosion close to the downstream toe.

In addition to the plain gravity reservoir or spillway type, notable progress has been made in the design and construction of large arch and rockfill dams. The experiments being made in California with a thin-section arch dam 60 ft. high and of 100 ft. radius indicate promising results.

Important advances are being made in the design and construction of auxiliary structures for dams, such as siphon spillways, control gates, flashboards, and other movable or automatic crests.

Earth embankments joining the ends of spillway masonry dams are being constructed more and more where conditions are favorable and suitable material is available.

Waterways, including both open channels and pipe lines, are now more economical from the hydraulic and structural standpoint.

The Trend in Hydroelectric Machinery

Hydroelectric machinery is less complicated and more efficient. The capacity of single main water-wheel units has increased from 5500 hp. to over 70,000 hp., while the efficiency has been raised from approximately 80 per cent to 94 per cent. Today the modern reaction hydroelectric unit is of the single-runner, vertical-shaft type, with generator mounted above and direct-connected to the water wheel.

This type of unit, especially for large capacities, predominates on account of its fewer parts, simpler construction, lower cost, and higher efficiency, as compared with the horizontal unit of the same head and power.

For heads up to approximately 50 ft. the propeller-type runner is fast displacing the Francis wheel. This runner, while somewhat less efficient than the Francis, operates at approximately 50 per cent higher speed and is somewhat cheaper; the largest saving, however, is from the decrease in size of generator and power house.

Impulse wheels for main units are invariably used for heads of more than 1000 ft. Larger-capacity units are usually of the two-runner, two-bearing, overhung type, one runner being mounted on each end of a single horizontal shaft, with the generator between the runners and the supporting bearings. Impulse-wheel units of the general design described and of 40,000 hp. capacity are in commercial service, and units of 56,000 hp. designed for 2500 ft. head are now being constructed. Vertical-shaft impulse wheels are uncommon but not impractical.

More knowledge is available on the characteristics of pipe lines, surge tanks, and transmission systems.

The operation of the power plant has kept pace with the general advancement. More attention is given to scientific methods for using pondage and storage. Regular inspection and maintenance schedules are followed, with the result that greater utilization of the energy from the stream is now obtained at less cost.

Development of Water Powers

Statistics show that the United States leads the civilized countries of the world in developed water power. It is estimated that our potential water power, available 90 per cent of the time, is approximately 35,000,000 hp., of which the present capacity developed is a little more than 10,000,000 hp. Of the undeveloped power some may never become economically available on account of restricted use of the stream flow, lack of market, prohibitive development cost, or other reasons.

Water-power developments are generally classed as low-, medium-, and high-head plants. The first classification may include plants up to 100 ft. head, the second to 500 ft. head, and the third all heads above this last figure.

Developed water powers are operated as isolated plants or in parallel with other prime movers. It is readily apparent that the isolated water-power plant can furnish continuous power only up to the amount produced by the wheels from the low or prime flow of the stream, and the amount of this capacity is dependent on the load factor of the system and the pondage available.

Contracts for prime hydroelectric power should not be negotiated beyond the power available from the minimum flows, except to the extent that the diversity of the load permits, as any power in excess of this amount necessitates relay power from some other source.

Isolated power plants as described are common for certain

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industrial plants, but are limited to supplying power up to their installed capacity from the regulated or unregulated flow of the stream, often necessitating a curtailment of the load below the full capacity of the plant.

In some instances when the stream flow is large and uniform, it may be that the prime power available cannot be completely developed, because of navigation, scenic, irrigation, or other requirements, with the result that power is available up to the plant capacity at any system load factor and can be used for industrial and public-service needs. The power plants at Niagara Falls and vicinity, and the large developed and undeveloped power sites on the St. Lawrence River, are examples of this class.

There are many examples of developed water powers operating in parallel with other prime movers, thereby utilizing the primary as well as large blocks of secondary power and energy in the system which they supply. Notable developments of this kind are in operation, as at Keokuk, Iowa, Big Creek and Pit River, California, Holtwood, Pennsylvania, and Bartlett's Ferry, Georgia. The hydroelectric development now under construction on the Susquehanna River at Conowingo, Maryland, is also of this type.

The Conowingo power site if developed to supply power and energy as an isolated plant would be uneconomical. The prime power of the Susquehanna River at this location under an average annual load factor of 50 per cent would be about 55,000 kw., but when the proposed plant is operated in conjunction with the Philadelphia Electric Company's system, as now planned, the initial installation of seven 40,000-kva. units will replace approximately 190,000 kw. of steam capacity and will economically deliver to the system at Philadelphia about 1,280,000,000 kw-hr. in the average year, over a transmission line approximately 70 miles long. It is estimated that this enormous amount of energy will conserve about 750,000 tons of coal annually.

A new method which is becoming popular for utilizing the wasted energy at inaccessible power sites on small streams, where the capacity is such that their development would be uneconomical if a regular operating force were required, is the electrically controlled automatic station. This type of station is usually electrically connected to and controlled from a distant central station employing the operating force. It may be fully or partially automatic, depending upon flow conditions of the stream and the service required. Reliable devices to control the operation of the hydroelectric machinery in automatic stations have been developed to such an extent that this type of station is entirely practicable.

Automatic hydroelectric stations containing one or more units having capacities up to several thousand kilowatts are in satisfactory commercial operation.

It is customary to think of a water power as utilizing only the fall of a stream, but at present there is considerable discussion concerning the development of hydroelectric power from the tides of the ocean. There is no doubt that in some locations where the rise and fall of the tides is great, large blocks of prime power can be developed. Whether projects of this kind can be successfully carried out will depend on the cost of the energy as produced and delivered to points of use, as compared with the equivalent energy obtained from some other source.

Outlook for Further Progress

The outlook for further progress in water-power development is most promising. The advantages of electricity are well known and its greater use will have an important bearing on the advancement of civilization. Our natural fuel resources, while still of large proportions, are not renewable, and even though they are not wasted their use decreases the supply available to the future. This is not so with water power. The flow of water from the land to the sea is an ever-recurring cycle. Its power is ever present.

The fact that approximately 70 per cent of this country's available water power is not being used emphasizes the need of intensive effort to obtain greater utilization of this great national resource.

The trend is toward greater economy in all phases of the art. Additional storage reservoirs on some of our streams would conserve the high flows and lessen or eliminate the flood menace. They would also materially increase the primary power and benefit navigation during the low-flow periods.

During the recent New England flood the benefit of storage developments was clearly shown in the Deerfield River in Vermont and Massachusetts. The peak of the storm, which amounted to 9 in. in 24 hours at Somerset, Vt., passed over this watershed without causing any flood damage, while all adjacent river valleys without adequate storage facilities suffered seriously.

The design of hydraulic structures is constantly being improved and construction methods are more economical. Water-wheel machinery has reached a highly dependable stage. Runner efficiencies will undoubtedly be higher in the future. Greater-capacity wheels will be built when the necessity arises, the limitation being dependent on the physical dimensions of the parts to be constructed and transported.

The propeller wheel probably presents more opportunities for improvement than the other types. We expect greater things from this runner in the future.

Hydraulic engineers continue valuable research work with model tests of hydraulic structures and water wheels, which contribute to lower construction costs and higher overall efficiencies.

The automatic hydroelectric station has made considerable progress. Its possibilities for expansion are very favorable. The redevelopment of antiquated water-power plants will continue, as usually by such redevelopment greater output results at low cost.

The power needs of our industries and public utilities are ever increasing. The requirements will be met by further power development and by combinations and interconnections of both hydro- and steam-power systems. Such combinations and interconnections will result in greater economy and flexibility in management and operation, and will eventually lead to the complete realization of the idea of the superpower system.

With the increased merging of power companies there will be a tendency to create more Federal and state regulatory boards. Herein lies an important problem which must be solved satisfactorily if new power development is to be encouraged.

If we may judge the future progress of water-power development by the work done in the past years, there can be no doubt that we will continue to improve our existing hydroelectric plants, and also construct new developments at those of our unused power sites that can be economically utilized.

A Large Electromagnet

FOR special research in physics, in particular, structural matter and the like, where instense magnetic fields are desired, an electromagnet of unusual size has been built for the French Academy of Scienes and installed at the National Office of Scientific and Industrial Research and Invention at Bellevue. The electromagnet takes 400 amperes at 240 volts and has in the neighborhood of 500,000 ampere-turns. This makes it one of the largest electromagnets ever built for purposes of scientific research. The original article gives the details of electrical design. (*Lé Génie Civil*, vol. 93, no. 4, July 28, 1928, pp. 91–93, 4 figs.)

Progress in Central-Station Use of Pulverized Coal

Summary of Experiences at Cahokia From Standpoints of Performance and of Dollar Value

By E. H. TENNEY,[1] ST. LOUIS, MO.

DURING the past eight years there has been a rapid improvement in the design of pulverized-fuel equipment, and a great amount of knowledge has been gained concerning it. Having worked out the major problems of preparation and of burner and furnace design for a wide variety of coals, we are now in a much better position to give the economic phases of the development greater attention. The difficulty in obtaining reliable cost data and the general reluctance to release unproved figures are probably accountable for the fact that many of the data given out up to this time have stressed technical rather than cost problems. This paper, although it contains many data that have already been published, is an attempt to assemble the experiences of powdered-coal development of the St. Louis central stations in a way to show their actual meaning from the standpoints of both performance and of dollar value.

The earliest central-station installations were designed and made largely on the knowledge and experience obtained in the cement industry. The problems incident to central-power-station operation, however, involving dependability of equipment and absolute minimum of outages, have been very different from those encountered in the cement industry, and have caused us to concentrate upon the technical aspects of the various operating difficulties as they have come up. It has been only recently then that we have been able to concentrate on the economic phases.

The Cahokia station of the Union Electric Light & Power Co., St. Louis, Mo., was the second central station in this country designed for pulverized coal, and in the three sections built consecutively over a period of six years most of the major developments in pulverized coal are represented. These developments have been along the following general lines:

(1) Power consumption of mills
(2) Wear on mill parts
(3) Drying equipment; its simplification or elimination
(4) Coal-transport equipment; reduction in wear on it, or its elimination by unit mills
(5) General improvements in combustion by control of fineness of grind; by burner and furnace design; by preheated air
(6) Furnace-refractory erosion; its reduction by use of water walls
(7) Slag and its elimination by various means
(8) Increase in heat liberation per cubic foot of furnace volume leading to high ratings by use of water walls, greater turbulence, and preheated air
(9) Simplifying the disposal of ash
(10) General combination of the above improvements leading to adaptation of pulverized-fuel systems to districts offering coals of widely varying characteristics, and to markets offering very poor or "distress" coal.

Reference to Table 1 indicates the nature of the evolution of equipment with which our application to these problems has been concerned. (1) The initial installation in 1922 consisted of four refractory-lined furnaces served by 6-ton mills in a storage system. This furnace design is shown in Fig. 1, and data concerning it are to be found in Table 1 under "Boiler No. 3." (2) The next development was in 1924 when boiler No. 11 was installed with fin-tube side walls, and mills of 15 tons capacity were used in the coal-preparation plant. The general furnace arrangement, however, was very similar, except as noted in Table 1 and Fig. 2. (3) The next development was in boiler No. 14 in which the side walls are water cooled, with plain bare tubes recessed into refractory. (4) Then followed boiler No. 13 with fin-tube side walls and air preheaters. (5) Finally boiler No. 17 was equipped with complete water-cooled walls and air preheaters, and was served by direct-fired mills and horizontal burners.

The discussion of the various phases of these developments will include: (1) maintenance, (2) operation, (3) fixed charges on invested expenditures, and (4) capacity and outage for repairs. It is realized that cost and performance records on separate parts of station equipment are difficult to obtain with exactness. By taking yearly averages, however, and by checking a summation of individual costs against accounting records, a degree of accuracy sufficient for comparison is assured. The data given in Table 1 are for the year 1927, and therefore represent performance on the early type of equipment after some operating knowledge had been developed. The comparison thus shows the differences inherent in the design and is not simply a record of progress from year to year in operation.

Fuel and General Boiler-Plant Design

The grade of fuel on which the plant is operated is shown in the following three analyses which cover the two grades used and an average for the year 1927:

	Illinois (Jackson County)		West Kentucky		Average, 1927	
Moisture	10.8	Dry	7.8	Dry	8.6	Dry
Volatile	33.4	37.4	34.3	37.2	34.1	37.3
Fixed carbon	40.7	45.7	46.4	50.3	44.9	49.1
Ash	15.1	16.9	11.5	12.5	12.4	13.6
B.t.u. as rec'd	10,700		11,640		11,394	

In burning qualities, the two fuels are similar, both having an ash-fusion temperature of about 2000 deg. fahr. The composition and quantity of the ash differ, however, and the West Kentucky coal can be burned with less excess air (except as hereafter noted) because of a lesser tendency to slag. In preparation the West Kentucky coal requires about 14 per cent greater power consumption and causes 16 per cent greater wear on the grinding parts.

The plant has been built in sections of eight 1801-hp. boilers. Two of these sections are complete and the third has three boilers in operation. The general arrangement is substantially the same for the first two sections, with sixteen 1801-hp. boilers fired from a storage system of pulverized coal. The preparation plant consists of waste-heat coal driers utilizing diluted flue gases as a drying medium. Roller or ball pulverizing mills and

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TABLE 1 BOILER COMPARISONS, CAHOKIA STATION

Boiler No.	No. 3	No. 11	No. 13	No. 14	No. 17
Date, initial operation	Sept., 1923	March, 1925	Dec., 1925	Sept., 1925	Oct., 1927
Boiler horsepower	1801	1801	1801	1801	1801
Fuel firing, pulverized coal	Storage	Storage	Storage	Storage	Unit mill
Burners	Vertical fan tail	Vertical riffle	Vertical riffle	Vertical riffle	Hor. turbulent
Air heater, sq. ft.	None	None	11,700	None	9,920
Side walls, sq. ft. tubes and tube spacing, c. to c.	Air-cooled refractory	Fin tube, 940 sq. ft., 7 in.	Fin tubes, 7 in., 905 sq. ft., plain, 10½ in., 66	Plain recessed, 324 sq. ft., 10½ in.	Plain recessed, 465 sq. ft., 7 in.
Front wall, sq. ft. tubes and tube spacing, c. to c.	Air-cooled refractory	Air-cooled refractory	Refractory, preheated air passages	Air-cooled refractory	Plain recessed, 93 sq. ft., 10½ in.
Rear wall, sq. ft. tubes and tube spacing, c. to c.	Plain tubes, 223 sq. ft., 10⅞ in.	Fin tube, 566 sq. ft., 7 in.	Fin tube, 540 sq. ft., 7 in.	Plain tube, 502 sq. ft., 10½ in.	Plain recessed, 238 sq. ft., 7 in.
Slag screen, sq. ft. tubes and tube spacing, c. to c.	Plain tubes, 358 sq. ft., 10⅞ in.	Plain tube, 382 sq. ft., 14 in.	Plain tube, 380 sq. ft., 14 in.	Plain tube, 503 sq. ft., 10½ in.	None
Hopper bottom, sq. ft. tubes and tube spacing, c. to c.	None	None	None	None	Bare iron blocks, 479 sq. ft., 7 in.
Total water-screen surface, sq. ft.	581	1,888	1,891	1,329	1,275
Fraction cold	0.26	0.63	0.59	0.59	0.79
Furnace volume, cu. ft.	11,750	13,500	13,200	13,000	12,000
Furnace volume, cu. ft. per rated hp	6.5	7.5	7.3	7.2	6.65
Distance arch to slag screen, ft.	22.0	22.5	21.5	22.5	....
Width of furnace top, ft.	17.8	20.7	18.7	18.7	19.2
Width of furnace bottom, ft.	16.0	20.7	18.7	18.7	19.2
Test Results					
Rating for best efficiency, per cent	150	185	190	185	165
Efficiency, per cent	86.0	86.75	87.15	84.85	88.85
CO_2 top 3rd pass, per cent	13.0	13.2	14.7	12.5	16.1
Total steam temp., deg. fahr.	670	656	670	686	685
Heat liberation, B.t.u. per cu. ft. per hr.	9,400	10,000	10,400	10,600	9,800
200 per cent rating:					
Efficiency, per cent	83.5	85.5	87.15	84.2	88.2
CO_2 top 3rd pass, per cent	12.7	13.2	14.6	12.5	15.9
Total steam temp., deg. fahr.	705	670	680	700	695
Heat liberation, B.t.u. per cu. ft. per hr.	12,900	11,000	11,000	11,500	12,000
250 per cent rating:					
Efficiency, per cent	81.0	81.4	86.85	81.7	87.05
CO_2 top 3rd pass, per cent	12.3	13.3	14.4	12.7	15.7
Total steam temp., deg. fahr.	725	705	720	720	705
Heat liberation, B.t.u. per cu. ft. per hr.	16,600	14,400	13,800	14,900	15,100
340 per cent rating:	Above capacity	Above capacity		Above capacity	
Efficiency, per cent	....	....	82.9	....	82.9
CO_2 top 3rd pass, per cent	....	....	14.1	....	15.1
Total steam temp., deg. fahr.	....	....	730	....	720
Heat liberation, B.t.u. per cu. ft. per hr.	....	....	19,600	....	21,600
380 per cent rating:	Above capacity	Above capacity	Above capacity	Above capacity	
Efficiency, per cent	....	....	....	....	79.7
CO_2 top 3rd pass, per cent	....	....	....	....	14.6
Total steam temp., deg. fahr.	....	....	....	....	730
Heat liberation, B.t.u. per cu. ft. per hr.	....	....	....	....	25,200
Operating Data					
Average operating rating, per cent	185	200	210	200	230
Operating efficiency, per cent	82.5	84.5	86.2	83.2	87.0
CO_2 top 3rd pass, per cent	13.0	13.6	14.9	13.5	15.6
Heat liberation, B.t.u. per cu. ft. per hr.	12,000	11,100	11,700	11,700	13,900
Maximum operating rating, per cent	200	240	320	240	400
Heat liberation, B.t.u. per cu. ft. per hr.	13,000	13,900	18,700	14,500	26,700
Limitation	Brickwork	Draft	Slagged tubes, smoke	Draft	Smoke
Operating Costs—Power Consumption					
Raw-coal handling, cents per ton	4.9	4.9	4.9	4.9	4.9
Ash handling, cents per ton	1.4	1.1	1.1	1.1	0.8
Slagging and cleaning boilers, cents per ton	1.9	1.8	1.8	1.8	0.7
Coal preparation:					
Operation, cents per ton	9.5	9.5	9.5	9.5	5.0
Maintenance, cents per ton	10.0	11.6	11.6	11.6	7.2
Power and lubricants, cents per ton	7.4	7.6	7.6	7.6	5.0
Total, cents per ton	26.9	28.7	28.7	28.7	17.2
Power consumption, kw-hr. per ton:					
Raw-coal handling, kw-hr. per ton	0.4	0.4	0.4	0.4	0.3
Mills and exhaust fan, kw-hr. per ton	16.0	16.0	16.0	16.0	15.5
Drier fan, kw-hr. per ton	2.5	2.5	2.5	2.5	....
Air transport, kw-hr. per ton	3.3	3.3	3.3	3.3	....
Primary air, kw-hr. per ton	5.3	5.6	5.6	5.6	....
Draft fans, kw-hr. per ton	....	....	4.7	....	6.7
Feeder motor, kw-hr. per ton	1.0	1.0	1.0	1.0	0.4
Total power consumption, kw-hr. per ton	28.5	28.8	33.5	28.8	22.9
Cost at 0.3 cents per kw-hr., cents per ton	8.5	8.7	10.1	8.7	6.9
Boiler operation, cents per ton	25.2	25.2	25.2	25.2	23.0
Boiler feeder, draft maintenance, cents per ton	6.6	6.6	8.4	6.6	6.0
Boiler-setting maintenance, cents per ton	13.5	1.6	1.6	1.6	1.6
Boiler and furnace fuel economy, cents per ton	14.0	8.0	2.0	12.0	....
Increment, West Kentucky coal, cents per ton					
Summary operating costs, cents per ton	96.1	79.6	76.8	83.6	56.3
Increment over latest installation	39.8	23.3	20.5	27.3	....
Investment Costs					
Relative investment, boiler plant	1.000	1.056	1.173	1.039	1.139
Ratio of total hours available	0.68	0.78	0.79	0.80	0.82
Service-capacity factor, per cent	136	187	253	192	328
Relative investment, boiler capacity	1.000	0.768	0.631	0.736	0.472
Fixed charges per ton coal burned, dollars	4.62	3.55	2.92	3.40	2.18
Maximum capacity basis:					
Total operating costs and fixed charges, dollars	5.58	4.35	3.69	4.24	2.74
Increment over latest installation, dollars	2.84	1.61	0.95	1.50	....

NOTES: Furnace volume is measured from above center line of slag-screen tubes to center line of lowest boiler tubes, except on boiler No. 17. On this boiler the volume is measured from the lowest row of boiler tubes to the horizontal center line through the hopper throat.

Width of furnace measured between side walls or between inner faces of tubes.

Fin-tube surface based on half entire perimeter of fin and tube screen surface for boiler No. 14, based on entire tube surface. Plain-tube surface of boilers Nos. 13 and 17 based on projected diameter of tubes, and bare iron surface is actual block surface.

a compressed-air transport system complete the coal-preparation plant. Vertical streamline firing is used in furnaces which are substantially the same in size and shape. The boilers and furnaces of the third section are very similar to those of the other sections, the most important change being the use of unit mills with horizontal turbulent firing. Thus it may be seen that the general plant layout has been unchanged through four changes in furnace design, and that the boiler and furnace size and arrangement are not materially altered.

DEVELOPMENT OF MILL PERFORMANCE

The main problem in mill operation has been that of reducing power consumption and decreasing maintenance costs. When the first boilers (represented by boiler No. 3 in Table 1) were installed in 1923, mills having a capacity of 6 tons per hour were the largest available. Tests showed that these mills, which were of the roller type, required 17 kw-hr. per ton at that time, with 6 per cent moisture in the coal. When subsequent mills having a capacity of 15 tons per hour were installed, the power consumption on test averaged 13 kw-hr. per ton. These tests were made when mill parts were new and at full capacity.

In operation, however, the capacity of the mills falls off as grinding parts become worn, and the output falls as low as 11.0 tons on the large mills and 5.7 tons on the small. The effect of this change is to make the power consumption and operating costs proportionately higher on the large mills and consequently these items are about equal for the two sizes of mills. Better lubrication, more complete drying, and improved transport methods put into effect since the plant's early operation have reduced power consumption and costs for both mills. Because of the difficulty of handling repair parts for the large mills the maintenance costs are slightly higher than for the small

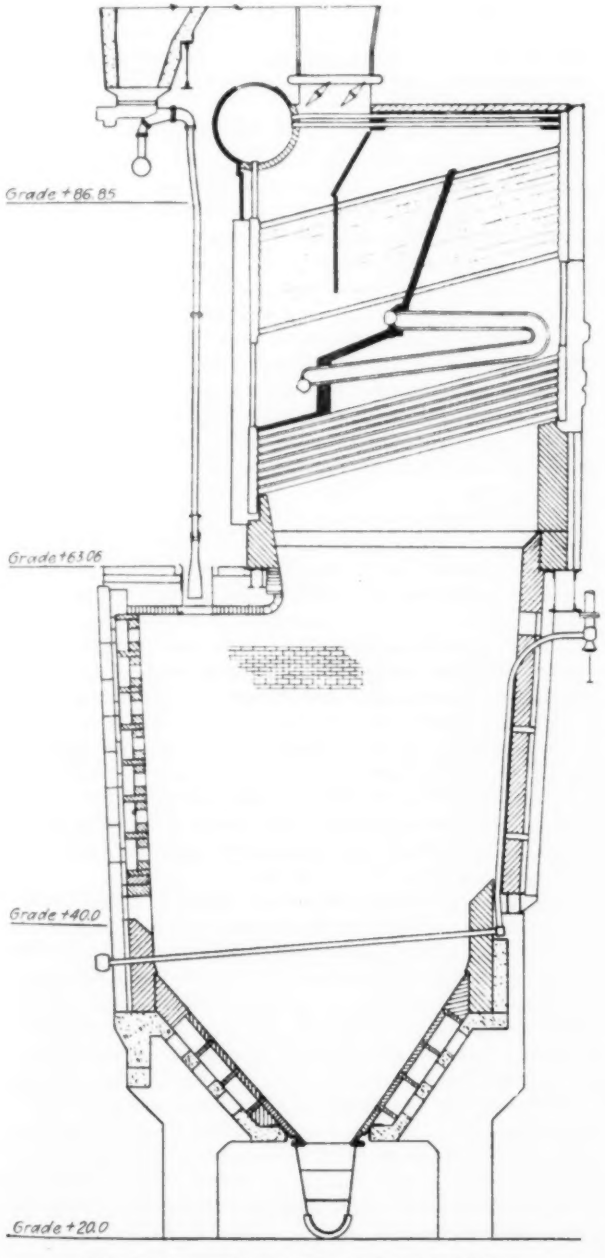

FIG. 1 BOILER NO. 3, REFRACTORY SIDE WALLS

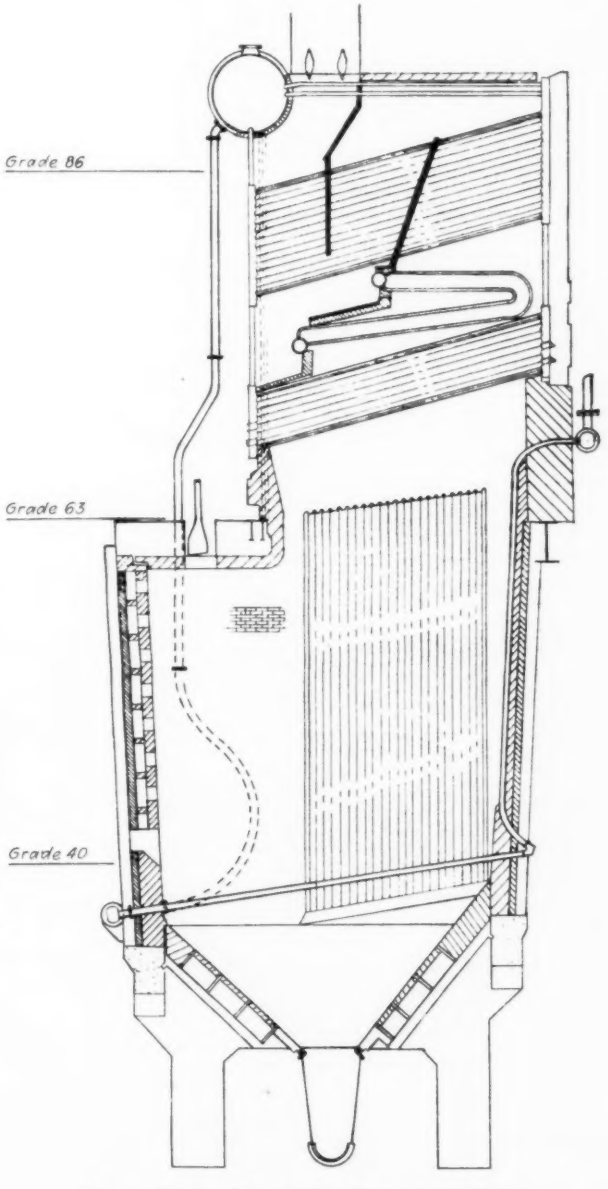

FIG. 2 BOILER NO. 11, FIN-TUBE SIDE WALLS

size. Thus, as shown in Table 1, the coal-preparation costs for boiler No. 3 are slightly lower than any of the three boilers of the second section, Nos. 11, 13, and 14, which are operated from large mills. It is not known just how far local conditions affect these results, but at least one other plant has had the same experience with 6- and 15-ton mills.

The change to unit mills in the third section has introduced new conditions. As may be noted in Table 1 the power consumptions for the mills are about the same. The overall power consumption, however, is reduced (1) by the elimination of drier fans; since the mills are of the high-speed, impact type and air swept, drying is not necessary; and (2) the elimination of pulverized-coal transport and primary-air fans is a further cause of lower overall power consumption. Due to greater accessibility with the new type of mill, the replacement of worn parts is somewhat less expensive, the overall cost of maintenance, including an item for deferred maintenance, being 7.2 cents per ton of coal.

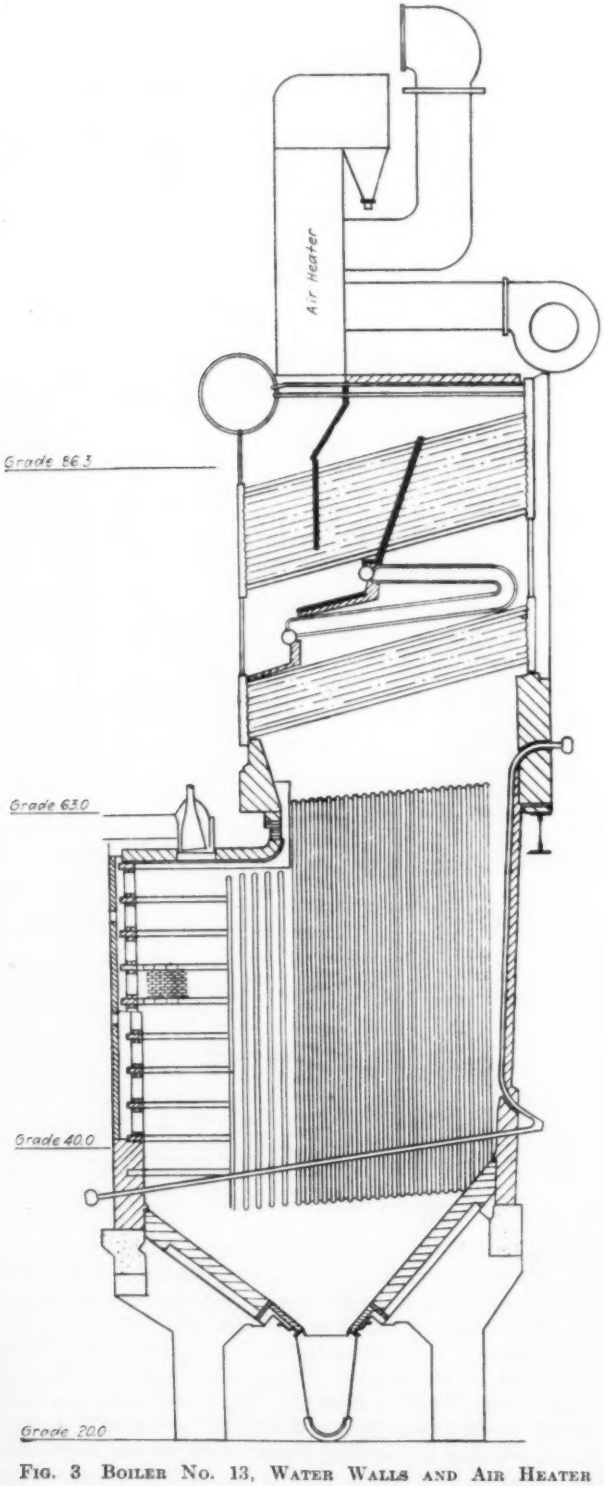

FIG. 3 BOILER NO. 13, WATER WALLS AND AIR HEATER

DRYING EQUIPMENT

Maintenance of the waste-heat driers, which utilize diluted flue gases as a heating medium, has been high because of high sulphur and moisture content of the coal and consequent corrosion of the sheet-iron plates. Considerable operating expense has also been involved in preventing damage from fires which frequently start in the driers and which must be located and removed before the coal reaches the mills.

COAL-TRANSPORT EQUIPMENT

Air transport systems, both the Quigley "shooting tank" method and the Fuller-Kinyon aerating pump, are used at Cahokia but separate costs are not available. The chief expense in transport has been that of replacing worn transport pipe and fittings, and in the operating attention required for stuck switching valves and for opening lines where the coal has packed.

As previously mentioned, coal-transport and drying equipment are eliminated in the third section by the use of the unit mills. This simplification has reduced the number of operators to the point where, in the third section, one mill operator and an assistant can care for the mills on eight boilers, compared to four or five operators for the same number of boilers in the other section.

FUEL FEEDERS, BURNERS, AND COMBUSTION PROBLEMS

Cross-sections of the feeder, burner, furnace, and water-wall arrangements for the five different types of boilers are shown in Figs. 1 to 5.

The pulverized-fuel feeders which are required with the storage system in the first two sections are subject to considerable wear and must be renewed after about 35,000 tons of coal have passed through them. The effect of this wear is to cause unevenness in the coal feed and irregularities in the fire. The burners originally used were of the "fan-tail" type, which is the type listed for boiler No. 3. A later design is the "riffle" burner which imparts a greater mixing action to the coal and air stream. Maintenance of fuel feeder and burner amounts to about 2.5 cents per ton with the storage system.

The type and design of burner have a marked effect on flame characteristics and combustion in the furnace. A streamline burner of the fan-tail type requires less primary air pressure than one of a mixing type, but results in the stratification of air and fuel and a longer flame. At high ratings, over 185 per cent on boiler No. 3, the flame shoots down through the slag screen into the ashpit and extends upward into the boiler generating tubes. Although the furnace volume is relatively large it has not been possible to effect sufficient mixing to cut down flame lengths and avoid slag in the ashpit. We have improved this condition, however, by imparting turbulence to the coal stream as it leaves the burners by placing water-cooled angle spreaders directly below the burner tips. It is reported that the improvement from such devices is much greater in some plants where coal of a lower volatile content is used. On the whole, however, furnace

performance with Illinois coal has not been satisfactory with the streamline, long-flame burners.

EROSION OF REFRACTORIES

With ash fusing at as low a temperature as that in the coal used at Cahokia, slagging and brickwork erosion can only be avoided by low ratings and high excess air. Although the walls in the brick furnaces are air-cooled, erosion can be avoided only by keeping the heat-liberation rate below 13,000 B.t.u. per cu. ft. per hr. Even at this rate the average side wall lasts about 4000 service hours and maintenance averages 13.5 cents per ton. The air-cooled brick walls and long-flame burners thus account for costs that are 19.5 cents per ton higher than is the case with mixing burners and water-cooled walls.

The mixing burner breaks up the coal stream and shortens the flame. Higher ratings and higher percentages of CO_2 are therefore possible without slag. A water wall of the fin-tube type (as in No. 11) or a wall of spaced tubes and refractory have effected a reduction in furnace-wall maintenance to 1.6 cents per ton.

SLAG AND ITS ELIMINATION

With reference to ashpit slag, the first four types of boilers are about on a parity, and have presented one of our most serious problems. Molten basic ash, combining as a flux with refractories having acid characteristics, even at moderate boiler ratings, runs down the side walls and collects on the horizontal water screen and in the pit where it gradually forms a solid mass. Before this can be removed the furnace must be allowed to cool for from 24 to 36 hours. As a result, the outage for removing slag has been as high as 25 per cent of the boiler service hours, and the average cost has been 1.8 cents per ton of coal.

Early in the station operation it was evident that slagging of the ashpits was greatly affected by, if not due to, the position of the hot zone of the furnace in or directly above the ashpit. Much effort was expended in attempting to develop ways of raising this hot zone to a higher point in the furnace. At about the time when this condition was most acute, a horizontal arrangement of firing was developed in the Ashley St. station on somewhat smaller boilers. Horizontal turbulent firing proved to fit in very well with the furnace conditions at that plant, and almost at once when the installation was tried out it became evident that slagged pits could be avoided, for the hottest zone of the furnace was no longer in the bottom, but up away from the ashpit toward the boiler tubes. A test installation with horizontal turbulent burners and unit mills was later made at Cahokia and the same furnace condition was obtained, i.e., the pit was kept sufficiently cool to avoid slagging. It was on the basis of this preliminary experimentation that the third section of the plant was equipped with unit mills and horizontal turbulent burners.

This latest installation has fully met expectations in that slag is not formed even with low excess air; the hot zone is now located midway between the ashpit and the boiler generating tubes; high boiler ratings are possible; and the efficiency is slightly better than on any previous installations. Other combustion conditions in the third section are similar to those in the earlier furnaces. Since about 70 per cent of the air required for combustion is used to sweep the mills, the rate of combustion is rapid. The turbulence possible with all air under pressure is a further surety that combustion is relatively complete in the shortened flame travel. With practically the entire wall surface water cooled, the furnace temperature is lower in the space close to those surfaces. This no doubt aids in the elimination of slag and makes high furnace ratings possible. It is, however, a limitation to furnace efficiency at very high ratings in that combustion is not as complete as in the case of the furnace with higher temperature. This loss shows itself in the amount of combustible remaining in the dust as it leaves the boiler. The net gain for this installation in operating economy, by avoidance of slag, by the elimination of coal drying and transport, and reduced operating attention, is listed in Table 1 and amounts to 40 cents per ton of coal compared to boiler No. 3.

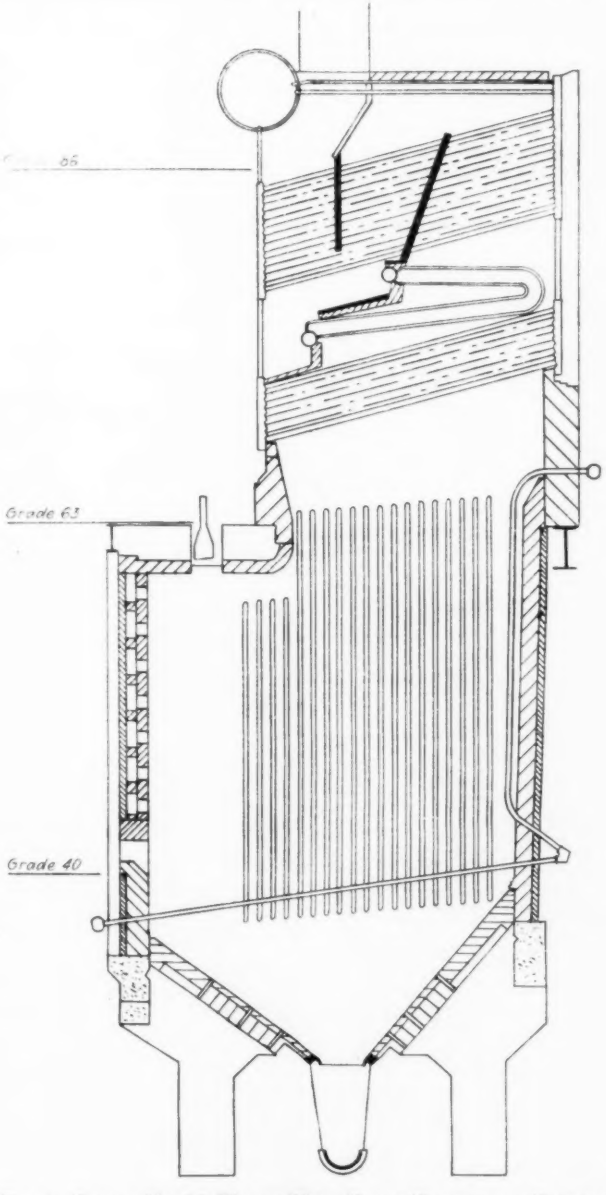

FIG. 4 BOILER NO. 14, WATER-WALL TUBES RECESSED IN REFRACTORY

AIR PREHEATERS AND GREATER HEAT LIBERATION IN FURNACE

Part of the gain in boiler efficiency with boilers Nos. 13 and 17 is due to air preheaters, and if a comparison is made with the efficiencies obtained with the storage system, it should be made with No. 13 boiler, which is identical in every way with No. 17 except for the method of firing. Economizers were not justified due to low fuel cost and turbine extraction heating, consequently air preheaters offered the remaining opportunity to increase boiler efficiency. As mentioned before, they also work to ad-

vantage with air-swept unit mills and turbulent firing. An additional advantage lies in the higher ratings obtainable with the forced- and induced-draft fans.

The various factors that have led to higher heat liberations in the furnace have been discussed, the most important being the use of water-cooled walls. The maximum rate of heat liberation has been increased steadily from 13,000 to 29,000 B.t.u. per cubic foot of furnace volume, the higher figure, of course, requiring forced- and induced-draft fans as used with air preheaters.

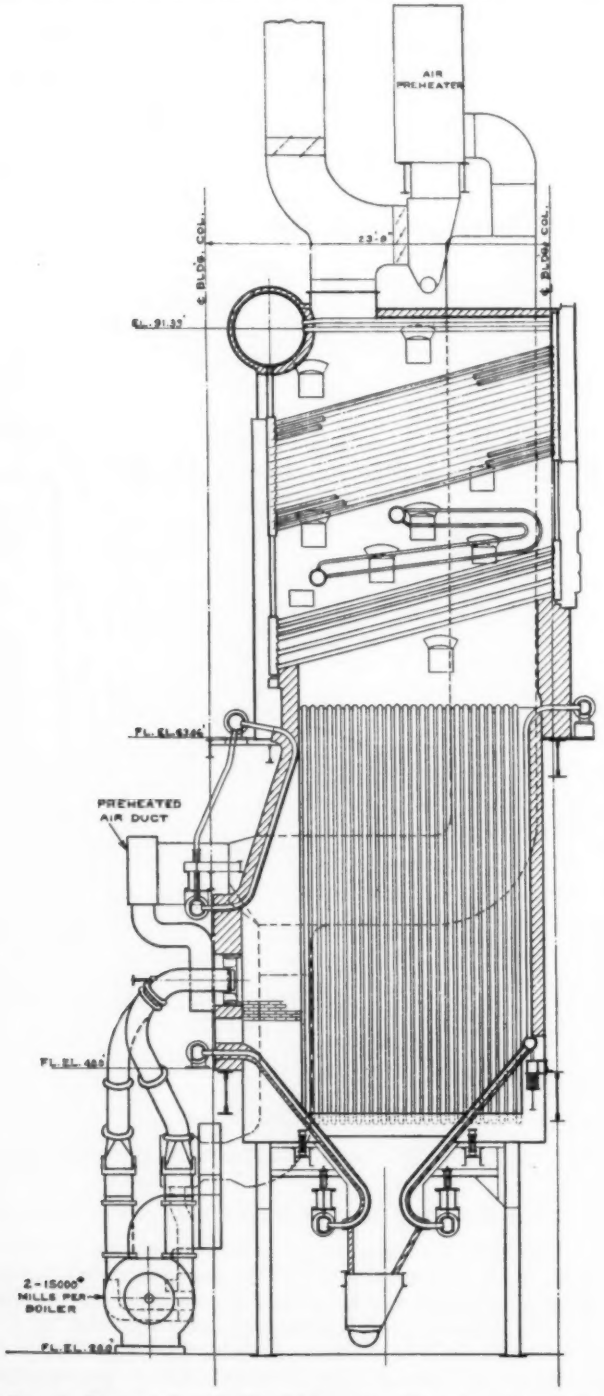

Fig. 5 Boiler No. 17, Unit Mills, Air Heaters, Complete Water Walls

The corresponding increase in maximum steaming rates for the various types of boilers has been from 200 to 400 per cent, which are the upper limits that can be obtained continuously without special preparation or attention. In the brick furnaces ratings higher than 200 per cent are accompanied by such rapid wall erosion as to limit the time of such capacities to an impracticable period.

Ash Disposal

By reducing the quantity of slag which must be removed from the furnace pits, a reduction in cost of ash handling and furnace cleaning has been effected. A sluicing system is used for removing granular ash and has proved to be very satisfactory. Heavy pieces of slag, however, cannot be sluiced and must either be broken up or carried out in wheelbarrows. The avoidance of slag in the latest boilers eliminates such work.

Adaptation to Wide Variety of Coals

The general combination of all the developments now places the design on a basis where a wide variety of grades of coal can be economically fired. The ash characteristics have proved to be one of the most important determining factors in burning any grade of fuel, and the solution of the slag problem permits the use of fuels which formerly could not be handled. Cahokia, during the past year, has operated on coal from two fields, going from one to the other as market conditions dictated. Other fuels burned have included coals from the vicinity of Troy, Illinois, having very high percentages of ash, and "by-product coke" from the oil industry containing practically no ash. The economic advantages of such possibilities are obvious.

Investment Costs

The entire development has, of course, been closely dependent upon first costs. The increased maximum boiler ratings have been accomplished with the same size of furnace and space occupied as the earlier installation, with a resulting reduction in investment per unit of boiler capacity. The figures indicating these changes are set forth in Table 1. To visualize more clearly what these comparative costs have been we have determined the investment for each boiler and converted it into a ratio, taking boiler No. 3 (of the original installation) as unity. Thus, boiler No. 17 cost 13.9 per cent more than No. 3, and so on. This cost includes complete expenditures for the steam plant, including coal and ash handling, building, coal-preparation equipment, boilers, furnaces, and all boiler-room equipment. These unit costs have been adjusted to a common basis of maximum steaming capacity. Thus, boiler No. 17 can be operated at twice the rating of No. 3, and the investment on a capacity basis is halved.

In setting up a capacity study, not only the boiler rating should be considered but also the relative outages for maintenance. Thus the early boilers have an outage factor for slagging and cleaning which is greatly reduced with the latest installation. On the other hand, the latest installation has an outage for repairs to unit mills. As a true measure of capacity, a combination of maximum rating and outages has been set up in a "service-capacity factor" as follows:

$$\text{Service-capacity factor} = \frac{\text{Percentage of maximum boiler rating} \times \text{Percentage of total hours boiler is available for service}}{100}$$

It is suggested that such a figure gives a truer indication of boiler performance than maximum rating alone. In using such a figure for comparison it must be realized that the outage for

repairs is partly under control of the operators, in that maintenance can be speeded up (at extra cost) when necessary. For comparison of boilers within a plant, or between plants of similar load factors, however, this factor is of value.

On the basis of the service-capacity factors the annual interest charges on investment have been calculated for the total tons burned in a year and prorated among the different types of boilers. The result is tabulated and shows that the latest installation compared to the first represents a saving of $2.05 per ton of coal burned.

That this is a tangible saving which can be realized upon is being demonstrated in a plant change now being carried out. Four of the first boilers are being changed to a type of firing and furnace construction similar to the most recent. A 35,000-kw. turbo-generator is being removed and a 75,000-kw. unit installed in its place, the new unit to receive steam from the same four boilers which served the original machine. Additional plant capacity is thereby obtained at an investment that is roughly 70 per cent less than the average for the plant.

CONCLUSION

In order to indicate the progress made with pulverized coal the operating records of a series of five different pulverized-fuel-firing arrangements and furnace designs have been assembled in such form as to show what value lies in each for this particular plant. These comparative values depend upon (1) the grade and price of coal used, (2) the plant load factor, and (3) the rate for fixed charges. With these conditions the design best adapted shows a saving of $0.40 per ton coal in operating costs and a saving of $2.44 in fixed charges. This result has been brought about by (1) reduction in coal-preparation costs, including the elimination of drying and transport equipment, (2) general improvement in boiler economy by development of the firing method best adapted to the fuel, (3) reduction in furnace maintenance by the use of water walls, (4) elimination of hard slag in furnace by horizontal firing, and (5) increase in ratings by the use of water walls, turbulent firing, and draft equipment. The last development has proved to be by far the most important in the matter of cost, and has been made possible by the experience with the other four developments.

In other words, out of previous experience there have been evolved furnace and firing arrangements which we believe to be better for Cahokia conditions than any that have gone before.

What the nature of further improvements will be is difficult to forecast.

(*a*) Improvement of mills will probably depend to some extent upon development of new types and on present designs, in maintaining the fineness of grind, and greater facility for repairs.

(*b*) The problem of higher rates of heat liberation in the furnace is receiving much attention. It will evidently require still greater flame turbulence and possibly higher furnace temperatures. Some installations are now obtaining rates of heat liberation as high as 60,000 B.t.u. per hour, usually by means of tangential firing.

(*c*) Water walls have about reached their limit with practically the entire furnace enclosed. Future attention will doubtless be given to lowering of installation costs of such walls and to possible improvements in water circulation.

(*d*) The use of radiant superheaters as a part of furnace walls offers possibilities in obtaining a higher and more even superheat. Radiant superheaters, being directly exposed to the temperature of the furnace, develop higher superheat with air preheaters and reductions in excess air, and are therefore affected in a manner directly opposite to that in which convection superheaters are by changes in excess air and furnace temperatures. A combined radiant and convection superheater is therefore more likely to give even superheat.

(*e*) Means for reducing the quantity of fly ash in the flue gases will be important where pollution of air is a severe local disadvantage. And, if the thought may be repeated, all these problems can be discussed to the greatest advantage if considered from a completely economical viewpoint.

Plate-Steel Rotor for an Electric Generator

AT THE Spring Meeting of the A.S.M.E. in Pittsburgh, H. G. Reist[1] presented a paper explaining in brief the construction of a 220-ton revolving-field spider for a generator driven by a vertical water wheel. In designing this spider the object was to obtain a construction having the least waste of material, ample strength, the fewest unknown quantities, and one which could be economically produced by existing shop equipment. The paper was published in the May issue of MECHANICAL ENGINEERING, p. 363. Discussions submitted by Messrs. C. Richard Soderberg and B. A. Behrend are given below.

C. RICHARD SODERBERG.[2] The mechanical design of the rotating parts for our modern generators, whether of the high-speed turbo type or the lower-speed salient-pole types, is one of the most difficult problems of mechanical engineering encountered in the electrical industry.

The author has described a construction which represents a radical departure from arrangements used so far, and which undoubtedly possesses the advantages which are claimed for it.

The Westinghouse Company has for years favored a construction which is very different from the one described by the author, but which has the same advantages. This construction is usually referred to as the "laminated-rim construction," and Fig. 1 shows the customary arrangement for rotors of comparatively small diameter. The centrifugal load is carried by a rim, stacked up from sheet-steel punchings. The central portion of the spider is made very light as it carries practically no centrifugal force, and its chief purpose is to center the rim and transmit the torque to the shaft.

Ordinarily, the rim is held by close-fitted bolts, linking the punchings together, but on some of the machines having thin punchings it is also possible to hold the rim by friction.

The actual strength of the rim, as compared to a solid rim, depends upon the amount of overlapping that can be used, and varies between 50 to 70 per cent of the strength of a solid rim.

Thus the actual effective cross-sectional area is smaller than in a solid rim, but this is offset by the certainty of a uniform material, and the superior quality of the material as compared to cast steel.

In machines of large diameter, as in the rotor described by the author, the construction shown in Fig. 1 does not have enough clearance or elasticity in the dovetails to permit the rim to expand under its load. This difficulty has been overcome by the

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[2] M.E., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa. Assoc-Mem. A.S.M.E.

construction shown in Fig. 2, which also indicates a structural-steel spider. This construction was originated by Mr. R. A. Baudry. The rim itself is not changed, but the dovetails engage in plates *A*, welded to the webs of the spokes, which permit elastic movements in the radial direction of the desired order. The rim is built up in the ordinary manner, and the axial bolts tightened up. Then it is heated to about 100 deg. cent., and wedges *B* are driven in. When the rim cools, it is shrunk on the spider with an allowance large enough to prevent loosening at the overspeed.

It is thus possible to extend the application of the laminated spider rim to any diameter within sight at the present time.

One of the most important advantages of the laminated-rim construction is the fact that the rotor can be assembled at the customer's power station without any previous assembly at the factory, and without turning the outside surface.

The material used in the rim can be adjusted to the requirements of each order, from the cheapest grade of bessemer steel for machines of low stress to high-grade alloy steels for the most severely stressed machines.

B. A. BEHREND.[3] The author's description of his new rotor design for the Conowingo generators is a most consistent appli-

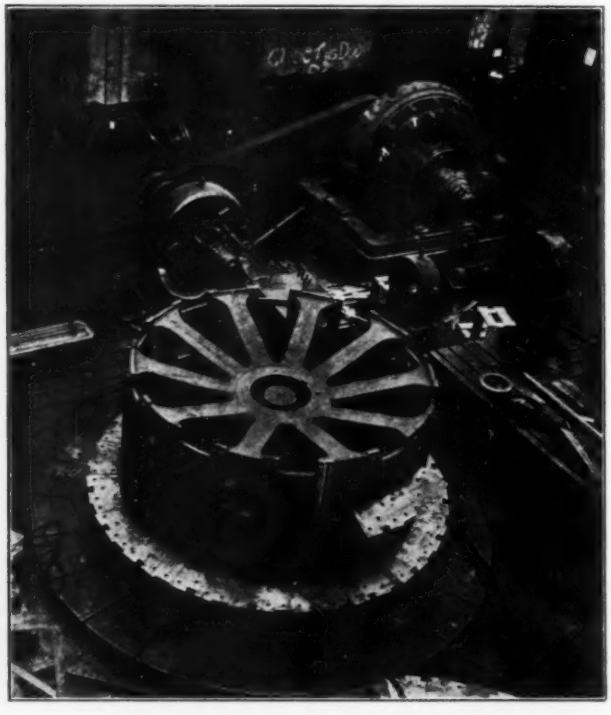

FIG. 1 CAST SPIDER WITH LAMINATED RIM

cation of the principle of utilizing throughout only rolled and forged materials. He has limited himself in this case to rolled materials only.

The most unusual part of the design is not so much the rotor spider as the rim, which is made up of cylindrical "leaves," so to speak, the separation being radial instead of axial as has been usual.

The author emphasizes that in slow-speed machines the arms do not as a rule contribute more to the relief of the cylindrical part of the rotor than they detract by introducing bending stresses. This is doubtless the case on slow-speed machines.

[3] Consulting Engineer, Wellesley Hills, Mass. Mem. A.S.M.E.

Twenty years ago rolled material was introduced into the manufacture of electrical machines by W. S. Henseley at a time when the industry was hardly ripe for it. Today, largely through the leadership of the author, frames and other parts of large electrical units are being made of rolled stock riveted or welded together. Thus a material advantage has been gained from the point of view of strength, ventilation, and cost.

For those who are not familiar with the design of high-speed revolving elements it may be remarked that the radial support furnished by a spider of continuous construction or by a disk, is very much depended upon to relieve the stress in the hoop portion of the rotor. This is of course perfectly well known to

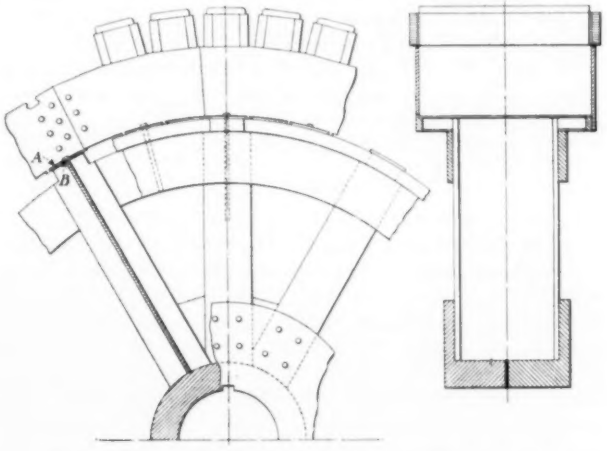

FIG. 2 STRUCTURAL-STEEL SPIDER WITH LAMINATED RIM

the author, who is not concerned in his paper with high-speed designs.

The writer believes the construction of these rotors to be sound in principle, and to mark a further advantage by securing greater strength and reducing uncertainty in regard to flaws, together with reduced manufacturing costs.

What Is Hardness?

BY HARDNESS is meant that property of mechanical resistance that is possessed by the outer layer of solid bodies.

It is now well known that bodies in thin layers have properties that differ widely from those they possess when they have considerable thickness, and their mechanical properties obey this law in the same manner as do their electrical, optical, or magnetic properties. When a layer of a given body has a thickness less than 50 micromillimeters, the usual properties begin to be modified; for still thinner layers there is still greater change, and the bimolecular or monomolecular layers of liquids or of gases no longer have the ordinary properties of liquids or gases, and they adhere to solids with a strength that was previously unsuspected.

For solids of appreciable thickness, the outer layer presents a phenomenon similar to the surface tension of liquids, except that the forces acting are very much greater.

In the case of tensile strength, it is well known that the finer the wire of any particular material the greater is the stress it can bear, and this stress increases with increase in the ratio of periphery to cross-section.

The definitions given above are rather definitions of the word "hardness" than of any corresponding and definite physical value, a definition of which has still to be found. R. Esnault Pelterie in *The Engineer*, Aug. 17, 1928, p. 180.

Modern Quantum Theories—II

In This Second Article Sommerfeld's Modification of Bohr's Model Is Discussed, and the Matrix Calculus of Heisenberg and the Wave Theory of Schrödinger Are Introduced

By LEON CAMMEN,[1] NEW YORK, N. Y.

IN A previous article[2] there was presented a résumé of changes in the theories of radiation from that of Maxwell, with the concept of a continuous process, to that of Planck, Einstein, and Bohr, with the concept of a discontinuous process involving quanta of action. That the quantum-of-action theory and the Bohr concept of the atom give a correct interpretation of radiation was established by Millikan, Compton, and others. The next step deals once more with the atom model.

Sommerfeld's Modification of Bohr's Model

In his model of the atom, Bohr gave to the negative electrons circular orbits about the positive nucleus, so that each atom became an infinitesimal solar system. According to Newton's law, circular orbits are possible, but only under certain specific conditions, which, as a matter of fact, are not believed to be encountered in the mechanism of the universe. Bohr needed, however, circular orbits in order to give to the constant N obtained from the Balmer-Ritz equation (referred to) consecutive integer values. As he built up his model with the definite purpose of meeting conditions imposed by data previously obtained experimentally, it was natural for him to resort to the use of circular orbits. If, however, the periodic motion executed by the negative electron about the positive proton or nucleus is under the influence of a force which is inversely proportional to the square of the distance as is the case in Bohr's model, it is likely that the orbit would be elliptical rather than circular. Sommerfeld modified the Bohr model so as to obtain elliptic orbits. For the semi-major axis of the orbital ellipse the same values are obtained as in Bohr's original theory for the radii of the circular orbits, but it was found that for every value of the major axis there may be a series of possible values of the semi-minor axis. (In Bohr's theory both axes were of course equal.)

In Sommerfeld's theory each orbit requires two quantum numbers for its definition—a principal quantum number n, and a subordinate quantum number k, which, however, can never be larger than the principal number. The principal quantum number determines the length of the major axis and the subordinate number determines the eccentricity, and therefore the shape of the orbit. If the subordinate number is equal to the principal number, the orbit is circular and the special case of the Bohr model is obtained.

If n and s are two principal numbers, theoretically ns transitions between the n and s quantum states are conceivable. There is, however, a so-called "selection principle" in operation, under which only those transitions are permissible in which the subordinate numbers vary by unity. A further modification has been the use of half-odd integers, as well as integers, as possible values of s, which considerably modified the older quantum theory. This will be discussed in a future article.

As regards the energy possessed by an electron in an elliptical orbit, calculation (too complicated to be repeated here) leads, in the first place, to the result that it depends only on the principal quantum number. The value given by this calculation for the energy in an n-quantum orbit is identical with that resulting from Bohr's theory of circular orbits, irrespective of the value of the subordinate number. The correctness of the results obtained in Bohr's theory is therefore in no way affected by Sommerfeld's development.

Thus, although the above calculation leads at first to the result that, for a given value of n, the energy in all the variously shaped orbits is the same, yet the calculation is based on the essential assumption that the elliptical motion of the electron under consideration is not disturbed in any way. On the other hand, if any kind of perturbation be present, the influence of the subordinate number must be felt, whether these perturbations be due to other electrons likewise revolving about the nucleus (which is always the case, except with hydrogen and ionized helium), or whether they be due to the establishment of an external electric or magnetic field. In these cases Sommerfeld's hypothesis of a subordinate quantum number proves to be extraordinarily fruitful. For in all these cases the energy values appertaining to the same principal number must differ from each other; hence, in accordance with Bohr's frequency condition, a so-called resolution of the spectral lines must take place.

It was, however, an especial triumph for the hypothesis of the subordinate quantum number that, in consequence of the different eccentricities of the orbits, the spectral lines, even in the undisturbed hydrogen atom, must be resolved. This resolution, which was predicted by Sommerfeld and which has also been completely confirmed by quantitative experiments, is simply a result of the minute correction to be applied to the above-mentioned calculations, when, in contradistinction to the classical mechanics, the theory of relativity is taken into account. Whereas classical mechanics leads to the result quoted above, according to which the energy for a given principal number is independent of the subordinate number, a certain degree of dependence is nevertheless found to exist when, in accordance with the theory of relativity, the increase in mass with increasing velocity is taken into account; for of course the velocities differ in the variously shaped elliptical orbits.

Efforts to Correlate the Theories

Because of the fact that the quantum theory explains certain phenomena which the wave theory could not, it does not mean that the wave theory must be completely abandoned. As a matter of fact, it still offers a satisfactory explanation of reflection, refraction, diffraction, and, to a large extent, dispersion of light of all wave lengths. It should be remembered, however, that in all these phenomena there is an interaction between radiation and matter, but no transformation of the energy of radiation into energy of other forms, or transformation or radiant energy of one frequency into radiant energy of another frequency. When it comes, however, to phenomena which involve a transformation of the radiant energy into another form, such as energy of the electrons bound in matter, recourse has to be had to the quantum theory. Furthermore, if the quantum be made small enough, i.e., making the wave length long enough, all quantum results must agree with the results of the wave theory.

[1] Associate-Editor, Mechanical Engineering.

[2] See Mechanical Engineering, vol. 50, no. 9, September, 1928, pp. 703–706.

This article does not present the results of original research, being merely a popularization of material already published. For further information readers should consult the references given at the end of the article.

According to Prof. E. N. daC. Andrade,[3] the immediate problem is less that of the fundamental reconciliation of the two theories than that of deciding exactly how far each can be employed in dealing with practical phenomena.

The most beautiful illustration of the difference between the two theories is shown by the consideration of phenomena of dispersion.

The wave theory supposes that when an elementary oscillator—an atom or molecule—emits light, this light spreads out in a homogeneous medium in spherical waves. In the case of dispersion the classical electromagnetic theory assumes that atoms contain linear harmonic oscillators consisting of electrons bound to equilibrium positions by quasi-elastic forces. These oscillations therefore have a definite free frequency ν_0. When a monochromatic radiation of frequency ν is incident upon them, they are set into forced vibrations of frequency ν whose amplitude depends upon the relation of ν to ν_0. The result of these forced vibrations is a modification of the velocity of the electromagnetic wave to an extent depending upon the frequency of the incident wave which produces dispersion.

Planck has shown that the results of the classical theory of dispersion can also be obtained by considering that the sole means of interaction between the molecules are electromagnetic waves originating in the vibrations of the bound electrons propagated in the free vacuum between the molecules. This left certain phenomena unexplained, however, particularly absorption, which, according to Lorentz, means transformation of the incident radiation into heat.

In attempting to explain dispersion by the quantum theory two methods have been used. One was to abandon the wave theory completely and the other to admit that as far as interference, dispersion, and such phenomena are concerned, quantitative description is based on the supposition that atoms emit spherical rays with the ordinary interference properties, which would mean that while the quantum theory governs interaction between radiation and matter, the wave theory gives a correct account of the phenomena outside matter.

To reconcile the two theories and to preserve the features in which the wave theory is successful, an assumption was made that the atoms give rise to a "virtual" field of radiation, which has the frequency determined by the quantum relation, $h\nu = E - E'$, and not by the frequency of the electron in its orbit, and that furthermore this field of radiation is continuous and not spasmodic as a true quantum field should be. This implies that the atom contains a substitute oscillator corresponding to each transition from an occupied orbit to another orbit permitted by the selection principle. It is obvious that if the substitute oscillator continuously emits waves capable of interference and has exactly the same properties as a classical oscillator, all the dispersion results which follow for the classical oscillator will follow for the substitute, since the dispersion is the result of the interaction of the spherical waves proceeding from the atoms.

The mathematical work of Ladenberg, Kramers, and others has shown that a dispersion formula may be obtained in this way, provided the wave theory be considered as valid outside the atom. Furthermore, Kramers has shown that his formula merges into the classical formula for the "polarization of the medium" when the quantum numbers tend to infinity, just as all quantum processes should do.

A remarkable feature of the hypothesis of substitute oscillators giving out energy steadily and continuously is that it implicitly denies that the principle of the conservation of energy and momentum holds for the atomic scattering process, because if an atom is put in a given stationary state, on the quantum theory it has a fixed energy until the stationary state changes abruptly, but if it is radiating spherical waves all the time it must apparently be losing energy.

On such consideration as was given this subject, it would appear that the principle of the conservation of energy and momentum holds only so long as large masses of matter are handled. Like the second law of thermodynamics, the law of conservation of energy and momentum is only, as expressed by Andrade, a macroscopic manifestation.

Bohr, Kramers, and Slater have put forward a theory which definitely dissociates the energy of the field of radiation and the energy of the atom as far as the single atom is concerned, and treats the conservation of the energy and momentum as statistical effects. The essence of the new theory is as follows:[4] When an atom is put into a given excited stationary state, it is to be considered as immediately starting to emit a steady train of spherical waves and has to continue to do so until its stationary state changes. When the quantum jump takes place the emission of one set of monochromatic radiations ceases and the emission of another set begins. The continuous emission from an atom which is in a stationary state violates the principle of the conservation of energy.

On the original quantum theory there was a causal connection between the radiation transformation in distant atoms. A given atom would change its stationary state and emit a quantum of energy which would eventually be absorbed by another atom, causing a quantum switch to a higher energy state in that atom. On the new hypothesis there is no causal connection between the jump in one atom and that in another. In other words, the radiation is continuous, but a gain and loss of energy of the atoms is discontinuous. This denial of the universal application of the law of the conservation of energy and momentum should be taken, however, with a very strong mental reservation. In the first place, there are not enough facts to support it. In the second place, there are actual experiments which would indicate that conservation of energy and momentum applies to certain interatomic phenomena. Thus, the experiments on the impact of the electrons on atoms indicate that in this case there are present rather definite stationary states which can only be changed by the additional loss of determined quantities of energy, which means that the interchanges of energy satisfy the essential requirements of the law of energy conservation. It would appear, therefore, that at best the methods of interaction by virtue of the field, where the laws of the conservation of energy and momentum fail to apply, are limited only to the case of atoms at comparatively large distances from one another, if there.

Is the Mathematical Treatment Correct?

The foregoing summary represents what might be called the classical period of the development of the quantum-of-action theory. It left a number of things to be explained and, in fact, probably raised more questions than it answered. The following quotation from R. A. Millikan[5] is particularly fitting, as Millikan himself contributed an important share toward the development, and particularly the establishment, of the momentum theory.

"To be living in a period which faces such a complete reconstruction of our notions as to the way in which ether waves are absorbed and emitted by matter is an inspiring prospect. The atomic and electronic worlds have revealed themselves with beautiful definiteness and wonderful consistency to the eye of the modern physicist, but their relation to the world of ether waves is still to him a profound mystery for which the coming generation has the incomparable opportunity of finding a solution."

To a mathematical philosopher, if there be such a thing, there is

[3] "The Structure of the Atom," 3rd edition, G. Bell & Sons, Ltd., London, 1927.

[4] Ibid., p. 683.

[5] "The Electron," University of Chicago Press, 1924, p. 260.

however, a suspicious element in all the above. Putting it into colloquial language, "it is all too good to be true." Up to the point in the development of the quantum theory where we stopped, including Bohr's atom models, all the physical phenomena available could be expressed apparently in terms of simpler school mathematics, and particularly in terms of scalar quantities, or magnitudes not affected by direction. There was, however, always a definite suspicion among mathematicians that universal phenomena could not be completely and satisfactorily expressed in terms of scalars, but must involve the vectorial or directional element in order to be true. Moreover, there was also a not unfounded suspicion that what might be called "school" mathematics would not adequately express such universal phenomena as those which these theories have attempted to explain, and the fact that in the development of the quantum theory up to the point at which we stopped, these phenomena were so expressed, would indicate that we were dealing with a partial and not a complete expression of them. The work of physicists within the last three years, in particular that of Heisenberg, deBroglie, and Schrödinger, has gone much further than is stated above. Up to the point at which we stopped, the quantum theory postulated the existence of stationary states of the atom (Bohr) calculated by the use of the classical mechanics and selected by the use of quantum conditions satisfied by the action variables of that theory.

In the new mechanics the equations have the same form as in the classical theory, but the variables no longer satisfy the commutative law of multiplication, i.e., xy is not necessarily equal to yx; the quantum conditions of the older theory are replaced by equations which enable the difference $xy - yx$ to be calculated, but nevertheless these equations involve Planck's constant h.

Kramers and Heisenberg worked out the absorption and scattering of radiation by an atom (regarded as a multiple periodic system in the classical theory) perturbed by an incidental radiation. They found a result expressed in terms of the orbital frequencies and amplitudes, and this result they translated into one containing experimentally observable magnitudes, namely, the frequencies and amplitudes of the spectral lines emitted by the atom. Heisenberg then developed a scheme of quantum kinematics by which the quantum formulas, which by this time had become quite complicated, would be obtained directly in terms of these experimentally observable magnitudes, i.e., frequencies and intensities of the spectrum, and without the intermediate use of orbital frequencies and amplitudes which by their nature can probably never be observed. The mathematical expressions obtained were, if anything, even more involved than before, but they were of a character that permitted a direct verification by experiment. The original dynamical quantity was expressed by a line of one-dimensional terms of substantially a Fourier series. Now, on the new quantum theory, it is represented by a two-dimensional table of terms or "matrix," and the development of the matrix mechanics by the subsequent investigators is as brilliant a piece of mathematical-physical work as has ever been seen.

SCHRÖDINGER'S WAVE THEORY

A considerable complication of the Bohr theory of the structure of the atom had been introduced sometime previous to the use of matrix mechanics. In the Bohr theory the proton or positive nucleus is a sun and the negative electron spins around it planet-wise, but while like a planet it is constrained to stay in a definite orbit, it is not supposed to behave like a planet in another way, i.e., it does not spin around its own axis. In 1925, however, Goudsmit and Uhlenbeck proposed their theory of the spinning electron according to which the electron was supposed to be spinning about an axis like a top. Heisenberg and Jordan then, using the new mechanics and the spinning-electron theory referred to above, calculated the structure of what is known as the doublets of the alkalies and in this way cleared up a number of problems, among others, the precession of the spinning axis of the electron, which were unsolved up to then.

All of this led to another great advance toward the comprehension of the atom made by Schrödinger, who assumed that the dynamics of an atom cannot be represented by a point moving through the coordinate space as in the classical theory, but must be represented by a wave in that space, and who obtained a differential equation which the wave function must satisfy. This equation contains E, the total energy of the atom, and has solutions which are continuous and bounded in the coordinate space only for certain definite values of E with corresponding wave functions. These values of the total energy of the atom E are the "energy levels of the atom," and Schrödinger's wave mechanics brings the whole new quantum mechanics within the scope of the differential-equation analysis and reduces the calculation of the intensities of the lines to a series of integrations, thus establishing practically a new calculus.

Incidentally, this happened. The quantum-of-action theory naturally led to the reinforcement of what might be called the corpuscular theory of the electron. When this seemed to be fairly well established, Schrödinger showed that probably it was all wrong, and that it was not a point but a wave that was moving. The most recent development in quantum mechanics is an attempt to reconcile the classical quantum theory of Planck, Einstein, and Bohr with the wave mechanics of Schrödinger and the matrix calculus of Heisenberg.

WHY IS THE ENGINEER INTERESTED?

The question may arise as to what interest the mechanical engineer has in these lofty realms of physics dealing apparently with problems far beyond the field of mechanical engineering. If it were certain that these are problems outside of his field, there would be no reason for the mechanical engineer to worry about the structure of the atom or the displacement of lines in the spectrum. There is, however, no such certainty. The physics of today is the engineering of tomorrow. If, thirty years ago, an engineer were asked whether an imaginary quantity would be of practical interest to him, he would probably have replied that engineering deals in real and not in imaginary things. Yet how could such a very real piece of machinery as an electric transformer be designed without the help of imaginary quantities? The engineer is already dealing with submolecular phenomena and the metallurgist is beginning to look to subatomics for the explanations of certain very common processes, such as, for example, the hardening of steel. Just how soon such an apparently abstruse matter as the Schrödinger wave theory or the Heisenberg calculus will be converted into terms of engineering is not certain, but there is scarcely any doubt that this will happen. Under these conditions it is well for the engineer to be prepared.

BIBLIOGRAPHY

R. A. Millikan, "The Electron," Univ. of Chicago Press, 1924.

Geo. Birtwistle, "The Quantum Theory of the Atom," 1926, and The "New Quantum Mechanics," 1928, University Press, Cambridge.

Karl K. Darrow, "Introduction to Contemporary Physics," D. Van Nostrand Co., New York, 1926.

Arthur Haas, "Introduction to Theoretical Physics," 2 vols., D. Van Nostrand Co., New York, 1926.

Arthur Haas, "The New Physics," E. P. Dutton & Co., New York, 1923.

H. A. Lorentz, "Lectures on Theoretical Physics," vol. 2, Macmillan & Co., New York, 1927.

John Mills, "Within the Atom," Van Nostrand, N. Y., 1923.

E. N. daC. Andrade, "The Structure of the Atom," 3rd edition. G. Bell & Sons, Ltd., London, 1927.

Recent Improvements in the Manufacture Of Flat Glass

AT THE Spring Meeting of the A.S.M.E. in Pittsburgh, a paper on the above subject was presented by H. K. Hitchcock, Consulting Engineer, Pittsburgh Plate Glass Company. The object of the paper, the author stated, was to touch on the early methods of making sheet glass; point out the generally accepted methods used; and briefly outline the most recent developments in the industry, giving references to the literature on the subject, so that those interested in it might be able to get in touch with the general line of this development without exhaustive search.

The author dealt first with the primitive, hand-operated ways of producing flat glass by spinning, blowing, and casting; the development of the use of power-driven machinery in casting, blowing, and drawing; and finally with the development of the continuous method of casting from tanks and grinding and polishing, with a brief description of an improved method of casting from pots. The paper, which was published in the May, 1928, issue of MECHANICAL ENGINEERING, p. 368, was the subject of much discussion. Of this, an extended written communication which was submitted and excerpts from the report of the session, follow.

J. W. CRUIKSHANK.[1] The author states a continuous ribbon of glass is made of a width up to 10 ft. The writer would like to ask where this has been done. It is a question of great interest whether glass can be rolled continuously from a tank in widths over 6 ft. Of course, theoretically, there is no limit to the width of the sheet produced by flowing glass from a tank and passing it through rolls, but in practice, based on the assumption that this process is similar to others, the width makes a great deal of difference. For example, in the annealing of glass in the leer and in the grinding and polishing on continuous tables, the difficulties increase enormously as the width is increased.

Referring to the melting tanks in which the author states the glass is of satisfactory quality at the beginning of the run, but becomes less and less so as the blocks wear away, the writer would ask whether this deterioration in quality is entirely due to the wearing away of the refractory materials of the tank or is due in part to devitrification in the mass. He has never been able to understand how a good quality of metal can be produced from a continuous melting tank, although he knows it is done.

The depth of the molten glass in a tank furnace is some 60 in., and it has been demonstrated that only the surface is flowing. This would seem to indicate that poor and devitrified glass must at times rise up from the mass and get into the flowing stream. It would seem impossible to produce good glass continuously under these circumstances. The ideal way would be to keep a shallow flowing stream and use up all the glass that is in a molten condition. Unfortunately, this is impracticable and impossible unless some super-refractory can be provided which will resist the fluxing action of the glass materials.

Devitrification is one of the most difficult things to contend with in a tank, and while good progress has recently been made in improving the materials so that there is less liability to devitrification, it is one of the enemies of the continuous process. This is more especially true in such machines as the Fourcault where, in the bath from which the glass is drawn, and in the channels leading to it, the temperature of the glass has to be reduced to the temperature requisite to produce the correct viscosity for the production of the sheet of glass. This is where the American Window Glass Company has a distinct advantage in its process in that the temperature of the glass is kept well above the point of devitrification, at which temperature the glass is ladled from the tank and removed in the ladle to the cylinder-forming machine. It is during the time the glass is in the ladle, and in the pot from which it is drawn, that it has a chance to cool down to the correct temperature to give the required viscosity for drawing.

On the other hand, in the case of the Fourcault-type process in which the glass is drawn directly from a bath in connection with the main body of the metal in the tank, the fact of cooling the glass in order to condition it to the desired viscosity for drawing, at a comparatively low temperature of below 1900 deg. fahr., and the holding of it in a molten state at this temperature, tends toward devitrification. These conditions make a modification of the batch necessary, with a proportionate reduction of the lime. The writer would like to ask if the same conditions are not encountered, to a lesser extent, in the rolling of sheet glass directly from the tank. They are, he knows, at the Ford Motor Co. where they have to use a slightly softer batch than in plate glass.

The author did not mention the process of the Ford Motor Company for rolling glass from a tank. This is an extremely ingenious invention known as the "unconfined pool," and the writer would like to draw attention to it as it is considered to be the pioneer process for the production of plate glass by the continuous method. The process is well known, and is open to general inspection at the plant at River Rouge.

The Ford Motor Company in 1919 built a small glass plant at Highland Park, adjoining the Ford automobile factory, to experiment on methods of producing plate glass. The final outcome of the experiments was the installation of a small melting tank furnace, and two lines of continuous traveling tables on which the glass was ground and polished. The idea was to produce automobile wind shields, cut to size in the rough plate, so that when the glass was ground and polished the result would be equivalent to finished wind shields. An immense amount of trouble was experienced with their tank, but eventually, in the latter part of the year 1921, they were rewarded with a measure of success.

The River Rouge Glass plant, built in 1922, consisted of an equipment of four melting tanks 78 ft. long by 16 ft. wide with a complement of continuous grinders and polishers. This plant was designed for the production of ten million feet of polished plate glass per annum. The glass from these tanks is rolled out in a continuous sheet 42 in. wide, which passes directly into and through an annealing leer, equipped with rollers, provided for each tank. The glass delivered to the rolls from the tank flows through a narrow channel in which a sluice gate is provided. The volume of the flow is controlled by the level of the glass in the tank. This level is exactly regulated by feeding the batch materials to the melting end of the furnace at carefully timed intervals so that the exact level is maintained. The molten glass flows from a refractory chute on to a comparatively large roller 48 in. in diameter, which is the equivalent of a revolving casting table and is rolled out into a sheet by a small roller placed over it. The first apparatus used at the Highland Park plant was actually a traveling casting table in the form of an endless belt with iron slabs connected by chains passing

[1] J. W. Cruikshank Engineering Co., Pittsburgh, Pa.

around sprockets with the roller revolving over it. The width of the sheet is controlled by the peripheral speed of these rollers, or the traveling casting table and its roller, and is a function of the rate at which the glass is flowing from the chute from the tank. The operator constantly gages the width of the sheet; if it becomes too wide, the rollers are speeded up by a delicate control of the electric motor. If, on the other hand, it becomes too narrow, the relative speed of the rollers is decreased. This device is extremely ingenious and is described in U. S. patent No. 1,556,665 to Avery and Brown. An attempt was made to control the width automatically by electrical means. For this purpose small fingers or rollers were provided on each side of the sheet; depending on variation in the width of the sheet these fingers caused electrical contacts to be established, which, operating through relay control, regulated the speed of the motor. This, however, was abandoned in favor of the former manual method of control.

An interesting patent, U. S. 1,532,704, issued to Le Mare, assigned to Pilkington Bros., England, very clearly illustrates the action of the glass in its flow from a chute on to a traveling casting table which, as noted above, has been replaced by a roll. The object of this patent is to provide a method for keeping the edges of the sheet from becoming chilled; a precaution which would probably be necessary in a sheet of glass wider than that made at the Ford Motor Company's plant at River Rouge.

The grinding and polishing of the 42-in.-wide rolled glass from each tank furnace is done on two lines of tables, each traveling under a series of grinders and polishers. One of these lines is for grinding and polishing the first side and the other for finishing the second side. The tables, before they are coupled together, are 113 in. long. When first this plant was started the continuous sheet of glass coming from the annealing leer was cut into lengths of 113 in. and laid on the individual tables before they were coupled to the line. This method, which was employed for some time, was later changed in favor of laying the rough plate sheets in any convenient length on the moving line of coupled tables. The advantage of this latter system is that the glass is laid in any size in which it is cut for obvious defects, especially for stone which would cause the sheet to break under the grinders. A further advantage is that when breakage occurs for any cause, pieces of glass do not have to be found of the exact size to match up the broken pieces on the individual tables. The latter method of keeping the rough-plate sheets in as large sizes as possible is similar to that practiced in the plate-glass factories of the intermittent casting system, where sheets from 200 to 300 sq. ft., are produced. The object of performing a minimum of cutting on the rough plate before the grinding and polishing is that obviously after the glass is transparent, defects can much more readily be seen. The author has described a very clever and unique arrangement of examining the continuous sheet of glass as it travels from the annealing leer with the use of nicol prisms by which defects can be detected. He also states that the glass is cut in "standard lengths so that instead of having a big variety of sizes which it is necessary to grind and polish, practically all of the glass which goes into the grinding and polishing departments is of standard sizes." It is evident from this statement that there are few defects found in the glass when examined at the end of the leer, and that most of it can be cut to sizes which will afterward cut to best advantage in the finished product.

The cutting of the polished plate glass at the Ford Motors Company is systematized to a high degree. The examiner makes an examination of the sheet, marks the defects and, in accordance with its quality, marks it off into sizes which are destined for wind shields, body glass, or shields for tractors.

The method of handling the glass described by the author in laying and removing it from the tables of the continuous grinders and polishers is very ingenious and well developed. However, it would seem that too much emphasis is being placed on the methods employed in the new system, for, with the exception that in the grinding and polishing department the tables are continuously moving under the grinder and polisher heads, replacing the round tables and intermittent operation, there are many features in which there is little novelty. The grinders are the same with iron-shod runners using varying grades of sand and emery. The polishers have felt-covered blocks with circular runners the same as used in the round type of machines. The carrying of the glass sheets may be considered to have been one of the greatest improvements in the industry before the continuous system was thought of, and was of immensely greater benefit in the handling of the large sheets of glass some 12 ft. high by 20 ft. wide, than the handling of the smaller sheets in the continuous system which is only a matter of efficiency. A gang of sixteen men carrying a sheet of glass weighing some 1500 lb., formerly employed in the old system, was later replaced by a traveling crane and a small clamp carrying the sheet. This was a notable stride in the industry. The vacuum cups to remove the sheets from the table were also developed and have been in use in most factories in Europe for a considerable time, and have also been used with a different form of apparatus in several plants in this country. The sand grading, and the dipping and cleaning of the glass were all previously in use, modified somewhat to suit the new conditions of continuous grinding.

In regard to the question of the melting of glass in pots rather than the employment of the continuous melting tank furnace, the writer has long held the opinion, and it would appear that the author is in agreement, that the pot method is superior. There is some development going on at the present time with the continuous tank, and installations are being worked out in England and in continental Europe which the sponsors are confident will be successful. For this reason it is difficult to obtain from those conversant with the glass industry, any admission that the tank is not superior and has not more economic possibilities than melting and rolling glass produced in pots.

Plate glass, as the author has explained, has always been melted and refined in pots in pot furnaces, and, up to a few years ago, the average plate-glass superintendent and technical man has always maintained that it was impossible to produce the quality required by the use of the continuous melting tank. It has now been demonstrated that this, to a certain extent, is a fallacy and the enthusiasts point to the window-glass and bottle-glass development as a precedent in the industry, where the same conditions prevailed at one time and the old-fashioned people connected with the industry believed that the pot was the only thing, more especially for glassware where high quality was the desideratum. However, in the plate-glass industry, the conditions are such that if by modern methods and the casting between rolls, such as the author has described, a thinner sheet of glass can be produced of approximately double the area from a pot, then the unit cost of the glass will be approximately cut in half. Some of the items of cost must necessarily be higher in the pot furnace than in the continuous melting tank; the consumption of fuel is undoubtedly slightly greater, and the cost of pots is a considerable item, but these differences are probably more than offset by the lower cost of repairs to the pot furnace, and the loss of glass and resulting increase of cost when the glass in the tank goes bad. In the case of pots there is always an opportunity to correct this bad quality when such develops, as each furnace is a unit in itself and each pot again a unit of the whole; whereas the tank, containing tons of metal, may have to be shut down, or an immense amount of glass drawn from it to correct the unfavorable conditions.

The method of casting the pot of glass, pouring it between rolls forming a comparatively thin sheet of large area, and then cutting it up, was first introduced by Max Bicheroux in the factory of which he is manager near Aix-la-Chapelle, Germany. Mr. Bicheroux started with the idea of making a number of smaller sheets from a large one by the regular plate-glass process of rolling on a casting table and then cutting up the sheets. He later developed the system shown in Fig. 1 which is described in his English Patent No. 182,551 and also in U. S. Patent No. 1,665,427 recently issued to Von Reis.

Referring to Fig. 1, the upper inclined plane at the left is the tilting casting table or slab. Glass is poured from the pot on to

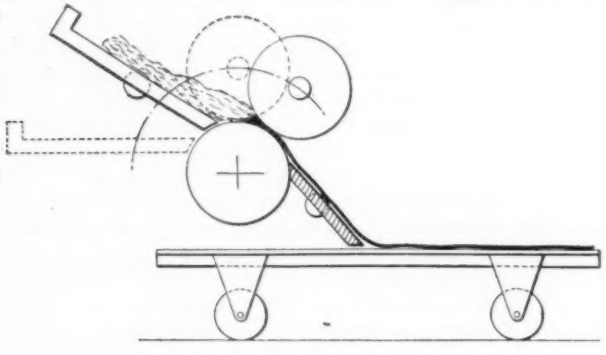

FIG. 1

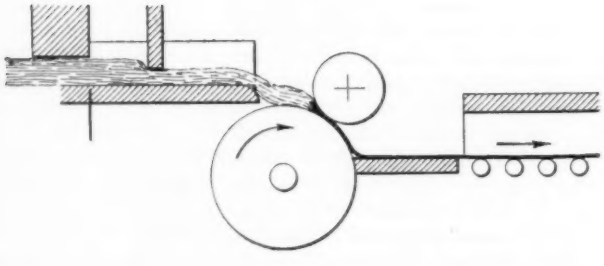

FIG. 2

this slab when it is in an approximately horizontal position. This slab tips up and is connected to the upper roll so that the two tip together. The glass is thus delivered to the rolls which revolve and the glass is passed between them and delivered as a sheet on to this lower inclined plate. There is a table mounted on wheels which travels at the same speed as the glass sheet coming from the inclined slab which is delivered on to the table and picked up by it. The table continues to travel over toward the annealing leer, where it is pushed over toward the oven of the annealing leer into which it is pushed. Recent patents on this device show a roller in the upper casting table slab so that the glass is fed to the rolls. They also have a roller to help the glass down the lower inclined plane to the traveling tables.

In the Ford process (Fig. 2), a chute leads from the glass-melting tank to a large roller. A small roller located above it rolls the glass against the larger one. The metal flows down continuously from the chute which is formed of refractory material, the flow being dependent on the regulation due to the level of the metal in the tank. The glass passes between the rolls and forms a sheet which passes to a series of rollers into the annealing leer through which it continually travels to the other end. The large roller is water-cooled, the water being kept always at the same level due to the fact the outlet at the other end of the roller is larger than the inlet on this side. The glass forms a pool from which the sheet is formed, the width of which is determined by the speed of the rolls and the quantity of glass that is delivered from the chute from the tank. A man provided with a gage measures the width, and if there is a variation it is regulated by the electric control of the motor.

The great point of saving in this system is the superiority of glass made in this manner, in that it is not only thinner, but has a more even thickness than the glass made by the old method, as well as being much straighter and flatter. The saving resulting from these qualities is very considerable in the grinding and polishing operation. Apparatus for rolling glass which is a modification of this system has been and is now being installed in several plants.

WALTER N. OAKLEY.[2] Some one has said that melting glass is analogous to melting ice in a vessel of sugar, and it is a fairly true analogy. Tank blocks in this service are made largely of clay mixtures composed of silica and alumina. As glass is highly reactive toward these materials at high temperature, a very serious corrosion problem exists. The temperature between the glass and blocks has to be accurately adjusted in order to minimize this corrosion. If the glass dissolves the blocks very badly it will spoil the glass. In order to minimize this attack the blocks are cooled on the outside and this in turn tends to cool the glass in the tank at the inside surface, and decreases melting rates.

Many attempts have been made to decrease this corrosion by adjusting clay mixtures so that they will have lower porosity and greater uniformity. Quite recently blocks were placed on the market which are cast from electrically fused mixtures. The porosity in this case is zero. These blocks wear at the rate of only a third of the ordinary clay blocks. Their use presents some very interesting possibilities to the glass manufacturers and users of processes involving molten materials.

W. TRINKS.[3] In the paper mention was made of the efficiency of the tank. Tanks are very inefficient now. If we consider the tank a machine, it has an efficiency of only $6^1/_2$ or 7 per cent.

I disagree with one statement made in the paper, namely, that in the Libby-Owens process the knurled rollers are there for the purpose of rolling down the glass. In this process the water cooling produces a stiff beam of glass which has sufficient strength against bending so that between the edges where the knurls are they roll the glass thinner; the final result is that the edges are a trifle thicker. The difficulty is to have the glass cold enough when it reaches the roller so that it will not be deformed too seriously and not lose its fire polish, and yet have it soft enough so it will bend over the roller without breaking or cracking.

W. L. ABBOTT.[4] Glass making is a very old industry as compared with other industries which are much larger. Glass makers are still groping with fundamental problems, and why? It is because they do not attend professional society meetings and freely interchange ideas as the steel men, the steam men, and the electric men do. They prefer to keep their troubles and their successes carefully guarded within their own walls and not to seek aid of their neighbors who have the same trouble and the same problems. It seems to me that if they would interchange information about what they have achieved and where they have failed that they would soon attain the success which has been experienced at the River Rouge Plant, where the advancement has been phenomenal.

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[2] Corning Glass Works, Corning, New York.

[3] Professor of Mechanical Engineering, Carnegie Institute of Technology, Pittsburgh, Pa. Mem. A.S.M.E. and Chairman of Session.

[4] Chief Operating Engineer, Commonwealth Edison Co., Chicago, Ill. Past-President A.S.M.E.

SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

AUTOMOBILE ENGINEERING

An Oil-Controlled Gear Shift

THIS device consists of a number of oil-pump cylinders mounted radially within an oil-filled cylindrical casing through which the driving shaft is connected and having pistons operated by connecting rods from a crank driving shaft. The action of the pistons draws oil into the cylinders, and this oil is either prevented from escaping, to obtain a positive drive, or permitted to escape at any required rate to cause relative slip, which is equivalent to gear reduction between the driven and driving shafts.

The device is the invention of Edmond Moglia, of Suresnes, and the Anglo-Continental Export and Import Syndicate, Ltd., of Paris.

As shown in Fig. 1, the trial unit has eight cylinders arranged radially in pairs with connecting rods attached to two cranks set

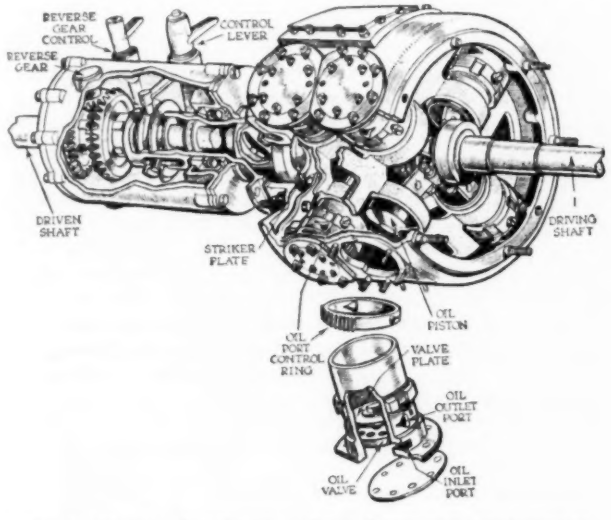

FIG. 1 MOGLIA OIL-CONTROL GEAR SHIFT FOR AUTOMOBILES

at 180 deg. on the driving shaft. It might be thought that four cylinders would have been sufficient and preferable from the point of view of cost, but under test it has been found that a greater number are needed to obtain a drive without torsional vibration. In the top of each cylinder is an inlet port and non-return valve through which oil can enter but not escape. On the side of each cylinder near the top is an oil outlet port that is opened or closed by partial rotation of a control ring. These rings are formed with teeth on one side, and those on adjacent cylinders are in constant mesh, and thus can only be rotated in unison though in opposite directions. The rings of one set of cylinders have projecting pins engaging with the outer ends of centrally pivoted levers, the inner ends of which engage with a striker plate mounted on the end of a sleeve. On the sides of the sleeve are cut two inclined slots, engaging with which are pins on an internal shaft that can be moved axially by a pivoted striker fork engaging with a grooved collar on the end of a shaft and operated by the change-speed control lever. By these means the striker plate is partially rotated, and the movement is conveyed by the pivoted levers to turn the oil outlet-port control rings to regulate the release of oil in the cylinders. The full movement of the ring is about 45 deg. The slotted sleeve and sliding shaft are enclosed within a steel tube, which is flanged and bolted to the rotating cylinder housing and transmit the drive to a simple forward and reverse bevel gear controlled by a separate lever. The control mechanism is enclosed in a stationary housing and both the driving and driven shafts are mounted on ball bearings.

When the control rings are turned to such a position that the outlet ports are open, the driving crankshaft will rotate without the cylindrical casing, since the reciprocation of the pistons is not opposed, the oil being merely pumped in and out of the cylinders. It will be seen that the ports in the cylinders and rings are pear-shaped, so that when the rings are turned the rate of oil release is progressively reduced; thus, as the rings are turned by movement of the control lever, at first the oil release is only slightly restricted, and offers small opposition to the reciprocation of the pistons, so that the casing is rotated very slowly in relation to the driving shaft. Further movement results in increased opposition and therefore reduction in the difference between the speed of the casing and the shaft. Finally, the oil outlets are entirely sealed, so that the oil is entirely imprisoned, and, as it is incompressible, the pistons cannot move in the cylinders, so that the casing is driven around at the same speed as the driving shaft. (*Motor Transport*, vol. 47, no. 1221, August 6, 1928, p. 164)

ELECTRICAL ENGINEERING (See also Power-Plant Engineering: Electric Steam Generators)

The Accupile Storage Battery

THIS is a French battery designed to reduce as much as possible the internal action. This was done by devoting special attention to the negative plates and involved the use of raw materials of special purity, the form of building up the grids, the preparation and formation of the active material, and finally the special mounting of the electrodes in the cell itself. The latter is of glass of sufficient thickness to obviate any risk of fracture. The electrodes are of considerable thickness and are spaced at a greater distance apart than usual in order to prevent short-circuiting owing to any breaking away of the active material. The bases of the electrodes rest on glass blocks, which also serve to prevent short-circuiting by any deposits of active material. The cells are hermetically sealed by a cover on which a special composition is run, which is only broken by the terminals and by a plug for the admission of acid and the escape of gases. The dimensions of the cell are such that there is a large reserve of electrolyte above the plates, while as the terminals are non-corrodible the cells can be relied upon to function for long periods without attention.

In a table is given a capacity which corresponds to a discharge rate varying from 1000 to 2000 hr. It is claimed that the electrodes normally lose less than 15 per cent of their capacity during three months and only about 30 per cent in six months. The cells can, therefore, be used in cases where they can be recharged at most twice a year. Discharge curves are given in the original article. (*The Electrical Review*, vol. 103, no. 2644, July 27, 1928, p. 145, 1 fig., *d*)

ENGINEERING MATERIALS

Nickel Aluminum Bronze

THE AUTHOR finds that bronzes containing 10 per cent of nickel and 2 per cent of aluminum may have their properties greatly improved by a special heat treatment. In the case of forged bars the hardness rapidly increases by tempering at 600 deg. cent. (1112 deg. fahr.) after quenching in water or liquid bath under 400 deg. cent. (752 deg. fahr.). The mechanical properties of such a bar have been found to be as follows: tensile strength, above 50 tons per sq. in.; yield point, above 35 tons per sq. in.; and elongation, above 25 per cent in 2 in. (Tokiji Ishikawa, *Journal of the Society of Mechanical Engineers*, Japan, vol. 31, no. 134, June, 1928, pp. 215–233, illustrated, in Japanese, *e*)

FUELS AND FIRING

The Atkinson Rotary Furnace

THIS furnace has been developed for firing Lancashire and water-tube boilers, particularly the former, and is said to have been operated for a considerable period of time before being placed on the market. Its first industrial installation was made in October, 1926, at the Sherdley Works of the United Glass Bottle Manufacturers, Ltd., St. Helens, England.

The rotary furnaces for each flue are mounted upon a common carriage. The furnace is constructed of mild-steel plate lined with cast-iron fire bars, and is given a slight inclination from the boiler toward the end from whence the clinker is discharged. The front ends of the boiler flues are lined with firebrick for a distance of 18 in., and into this lining is built a fuel dam which prevents the fuel passing from the feed hopper into the boiler and directs it into the furnace chamber. The furnace makes one revolution in 3 min. The fan supplying the blast is driven from a separate motor. The total power actually taken to drive the furnace feed gear and fan is from $4^1/_4$ to $4^1/_2$ b.hp.

However, exhaustive and independent tests show that when burning South Lancashire slacks of a calorific value of about 11,000 B.t.u. the efficiency of the boiler alone was 70.1 per cent; the efficiency, therefore, if economizer and superheater are included would certainly exceed 80 per cent. This remarkably high efficiency is due to a combination of circumstances. The constant movement of the fuel insures a constant depth and density of the fuel bed, so that the highest possible thermal efficiency is obtained; indeed, under the conditions specified, up to 17 per cent CO_2 readings have been maintained. There being no interruption due to cleaning fires, evaporation is regular and constant. The rolling movement due to the constantly changing position of the fuel bed tends to ball the finest fuel, and at the same time raises combustion to a point when no black smoke is formed.

In this furnace the fuel is drained slurry, which contains 30 per cent of ash on the dry basis, and, as fed to the boilers, approximately 32 per cent of moisture, the calorific value of the fuel being 5600 B.t.u. For the time being these furnaces are hand-fired, as obviously no form of chute would automatically deliver such material. A special apparatus is being designed for the purpose of mechanical firing. The boiler has an approximate evaporation of 8000 lb. per hr. at 150 lb. pressure, and the furnaces will burn up to approximately 19 cwt. per hr., the average combustible matter in the dry clinker being 8 per cent.

Another unit has been installed at the Old Boston Colliery, likewise at St. Helens. (*The Iron and Coal Trades Review*, vol. 117, no. 3149, July 6, 1928, pp. 4–5, 4 figs., *d*)

Diamond-Shaped Powdered-Coal Furnaces

A STIRLING boiler unit has been changed over to pulverized-coal firing under conditions which require an unusual method of solving the problem. The original furnace shown in Fig. 2 was installed in a 6110-sq. ft. Stirling boiler, having a double D-type overfeed stoker. This was changed over into a pulverized-coal furnace shown in Fig. 3. The diamond shape of furnace was developed somewhat by force of necessity, but is believed to possess some merit of its own, particularly in connection with existing plants. The furnace is 15 ft. wide from side to side of the boiler, approximately $18^1/_2$ ft. deep measured along the line of flame propagation, and approximately $12^1/_4$ ft. from the front bank of tubes to the front wall. It has a volume of 3384 cu. ft. or 0.55 cu. ft. per sq. ft. of original boiler heating surface. The bottom and two of the faces of the furnace interior are water-cooled, two are air-cooled, and two are solid. The unit has been in operation over $1^1/_2$ years without requiring furnace maintenance except for approximately $40. During this period an average rating of 200 per cent has been maintained, with daily peaks of several hours' duration at 240 per cent during the winter season.

Experience with this bottom shows that water cooling with plain tubes of extra thickness is effective, comparatively cheap, may be applied to almost any surface, and that pure water is not required. The cost of solid firebrick walls $22^1/_2$ in. thick and of first-class construction is $3 to $4 per sq. ft. of surface. The more elaborate types of air-cooled walls complete with insulation have been running $7 to $9 per sq. ft. Water-cooled walls (or bottoms) installed with plain tubes and without frills run but little more in cost than the best air-cooled walls when all elements of the cost of the job are considered. In some cases the writer believes the water-cooled job may be of the lesser cost.

The Atrita unit pulverizer was used in this installation. With little trouble, the internal arrangement of the machine may be modified to give considerable changes in the characteristics, particularly the fineness-capacity curve.

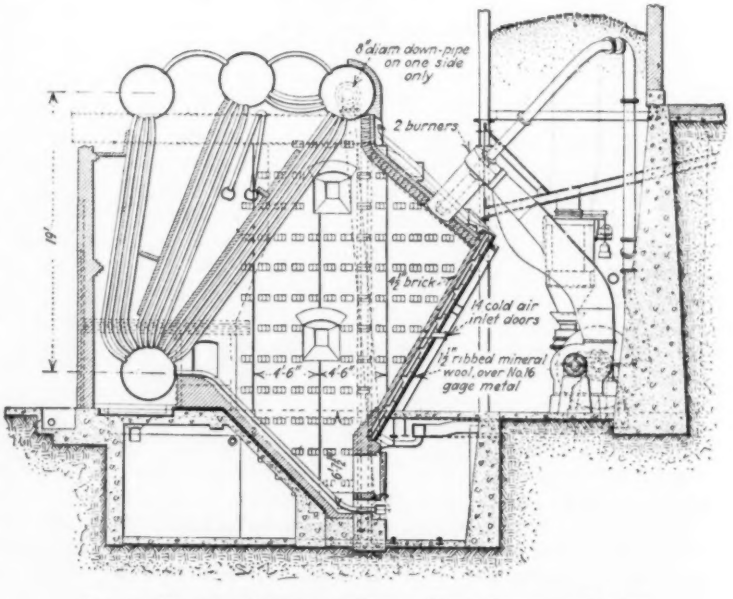

FIG. 2 ORIGINAL SETTING OF BOILER WITH OVERFEED STOKER

The life of a set of moving pegs was found to be approximately 6000 tons of coal, and the variation in fineness of the coal from new to old pegs is generally not more than seven or eight points on the 200-mesh Tyler screen. An illustration in the original article shows the uniformity of the wear of the pegs in proportion to the tons of coal pulverized to approximately 70 per cent through 200-mesh.

The actual maintenance cost of the pulverizer as now installed is 4.6 cents per ton of coal, including labor, with repair parts averaging about 15 cents per pound. In any pulverized-coal installation the interlocking relationship of the kind of coal, the fineness, the capacity, the wetness of the coal, and the power required is not lightly to be dealt with.

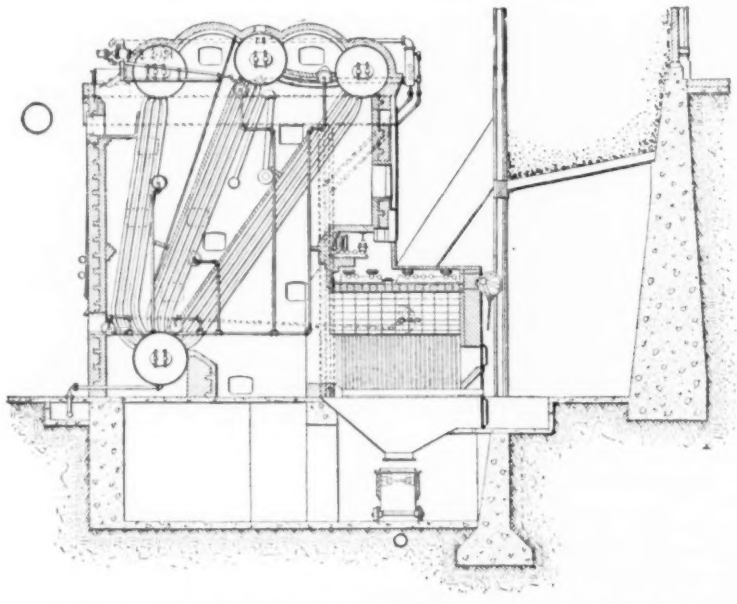

FIG. 3 BOILER SETTING SHOWN IN FIG. 2 AFTER REMODELING FOR UNIT PULVERIZER AND TWO BURNERS

In the writer's experience some coals require twice as much power to pulverize to a given condition as others, hence the pulverizer should be fitted with considerable care to the particular job.

A table giving results of tests and information as to the coal used is included in the original article. (Guy B. Randall in *Power*, vol. 68, no. 9, August 28, 1928, pp. 346–350, 11 figs., *de*)

HYDRAULIC ENGINEERING (See Mechanics)

HYDRAULICS

Mechanical Reliability of Hydroelectric Units—Propeller-Type Turbines

DATA for 1926 as compared with previous years show an increasing use of hydraulic power and an increasing reliability as indicated by the smaller range of outage-time percentages. It would appear also that there is a downward trend in outage toward the higher ratings of the units.

For the first time in these reports data are published regarding propeller units. In this case the propeller unit listed is rated at an output of 30,000 hp. It is of the vertical type with one runner to operate at a head of 60 ft. and at 120 r.p.m. It was installed in 1924. (Serial Report of the Hydraulic Power Committee, 1927–1928, Engineering National Section, National Electric Light Association, issued in July, 1928, 13 pp., including 6 tables and 3 figs., *s*)

MARINE ENGINEERING

One Pound of Coal per Indicated Horsepower per Hour

A POUND of coal per indicated horsepower per hour was regarded as the ideal toward which all marine-engine builders and operators directed their efforts. It is remarkable that only quite recently has it been approximately reached in two cases, namely, those of the high-pressure turbine steamer *King George V* and the high-pressure triple-expansion-engined ship *Borneo*. Still more recently, the figure is said to have been actually obtained by the "Beaver" class cargo liners of the Canadian Pacific fleet. So far as the results of turbine ships are concerned, further improvement is certain. In the case of the *King George V*, for instance, the relatively small power of the installation is divided into no less than seven turbines, and there is no doubt that the same type of installation of 10,000 to 20,000 hp., employing the same feed circuit, the same boiler pressure and temperature, would give an improvement of some 15 to 20 per cent.

The very fine results obtained in the Canadian Pacific ships were realized with a moderate boiler pressure of 250 lb. per sq. in. and a steam temperature of 650 deg. fahr. (Editorial in *Marine Engineering and Motorship Builder*, vol. 51, no. 612, August, 1928, p. 282)

The Beardmore-Caprotti Valve Gear

IN A recent issue of MECHANICAL ENGINEERING (August, 1928, p. 638) a description was given of the Caprotti valve gear as applied to locomotives. It has now been adopted for marine purposes, and Beardmore & Co., Ltd., have recently applied the system to a number of vertical triple-expansion marine engines.

The main feature of the Beardmore-Caprotti valve gear consists in the substitution of poppet valves for the ordinary slide valves. There are four poppet valves to each cylinder—one steam-admission valve and one exhaust valve being arranged at the top end of the cylinder and similar valves arranged at the bottom end of the cylinder. The valves are at the ends of rocking levers, these levers being in turn operated by cams arranged on a rotary camshaft. The camshaft itself is rotated by means of a vertical shaft which gears with the main crankshaft in much the same manner as that adopted for the camshaft drive of the Diesel engine. The four valves of each cylinder are controlled by three cams, two of these cams being for the admission valves, one of which controls the opening and the other the closing of the valves, imparting to the rocking levers a compound motion obtained from both cams. The third cam controls both the opening and the closing of the two exhaust valves. All the cams are fitted loosely on the camshaft and are driven in such a way as to permit of alterations in the cam's position relative to the camshaft. This relative movement of the cams is carried out by means of a simple hand-control gear which is led down to the starting platform. The cams run in an oil-tight bath which is located near the cylinders and as close as possible to the operating gear for the valves. The valves, being of the balanced double-beat type, require very little power for their operation, and, as a consequence, all the operating gear is of comparatively simple and light construction. Due to the elimination of the link motion, the total overall length of the new engine is reduced by an amount equal to 25 per cent of the ordinary engine, and there is also a considerable saving in weight, amounting to approximately 15 per cent.

The most important advantages of this valve gear are in respect to steam consumption with both saturated and superheated steam. Separate steam and exhaust passages are provided at both ends of the working cylinder which decrease the condensation losses and reduce to a minimum the clearance volume and all waste spaces. The valves need no lubrication and are therefore particularly suited for use with highly superheated steam. The throttle valve is always full open, the speed of the engine being controlled by varying the point of cut-off; consequently no wire-drawing takes place and as the compression is always constant, an almost ideal steam diagram is obtained and the looping of the diagram is entirely avoided. This is shown in Fig. 4, which gives indicator diagrams taken during the trials of the S.S. *Diamond*.

As an illustration of the installation of engines of this character it will be found that when the velocity of flow is extremely small the flow lines show a double symmetry with respect to the vertical planes passing through the axis of the cylinder. Of these planes one is normal to the direction of flow and the other parallel to it. As the velocity increases, the aspect of the wake in the horizontal plane becomes like that of Fig. 5. The flow lines are no longer symmetrical with respect to the plane passing through the axis of the cylinder in the direction parallel to that of flow. Back of the obstacle there are found two curves showing the presence of singular points (Fig. 6) which the authors call α and β. The greater the velocity, the more these curves are elongated. This corresponds to the Poiseuille laminary state in the wake of the obstacle.

Beginning with a certain velocity V_0, one observes the formation of whirls first on one side and then on the other side of the ob-

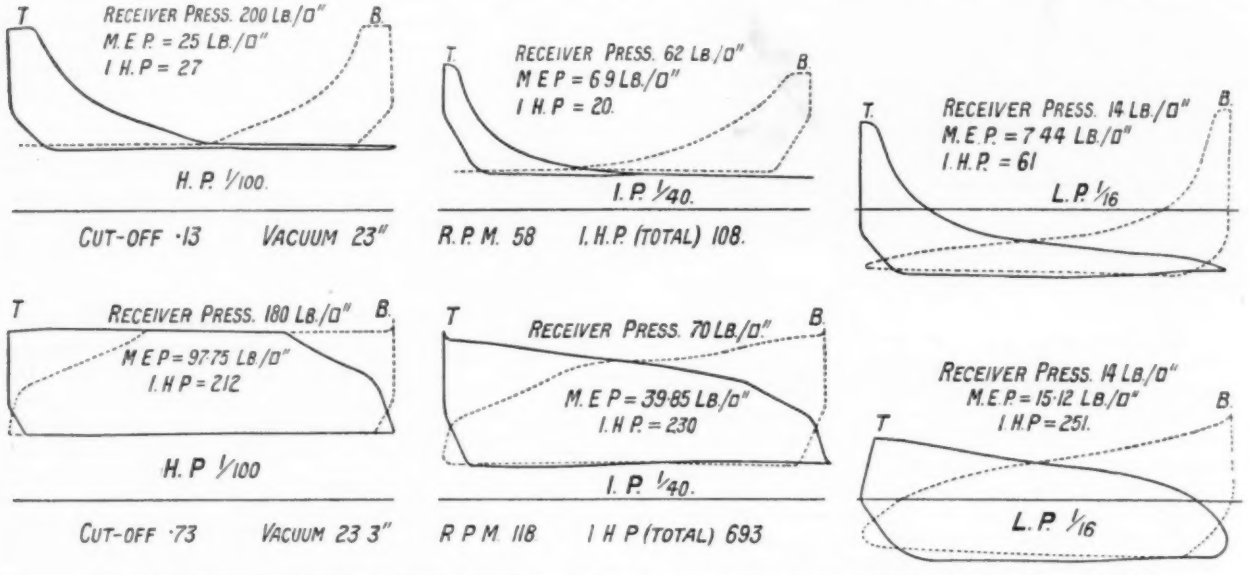

FIG. 4 INDICATOR DIAGRAMS TAKEN DURING THE TRIALS OF THE BEARDMORE-CAPROTTI ENGINE, S.S. *Diamond*

may be mentioned S.S. *Authority*. She has been built for carrying oil in bulk and has a length of 180 ft. She is propelled by a single triple-expansion engine fitted with Beardmore-Caprotti valve gear, steam being supplied by a coal-fired boiler. The main engines have cylinders 13.5 in., 22 in., and 37 in. in diameter with a positive stroke of 26 in., and are designed for a speed of 100 r.p.m. at 9 knots surface speed and to attain 10 knots when trials are being made.

The Beardmore-Caprotti valve gear is applied to all of the cylinders of the main engine and uses separate double-beat drop valves to control admission and exhaust. The cut-off is variable through the complete range of powers, both ahead and astern, and is altered equally in all of the cylinders. The arrangement allows the location of the drop valves for admission and exhaust to be on the side of the cylinders, reducing the length of the cylinders to 10 ft. where it would have been about 12 ft. with the normal type of valve. (*Marine Engineer and Motorship Builder*, vol. 51, no. 612, August, 1928, pp. 298–301, *d*)

MECHANICS

Benard-Karman Alternate Whirls

IF A FLUID with a kinematic coefficient of viscosity μ/ρ is made to flow around an obstacle, such as a vertical cylinder having a circular base, and the different aspects of the wake of the liquid are examined for various gradually increasing velocities, stacle, which whirls are carried away by the velocity of the flowing fluid and take positions along two parallel lines. This is the so-called "whirl street of Bénard." The presence of these whirls characterizes a new state which by analogy with flow in pipes may be called the turbulent state. Previous investigations do not seem to give a clear conclusion as to whether the law of dynamical similitude applies to the case of alternate whirls, and hence does not permit determining whether there is a well-defined Reynolds number indicating the creation of the turbulent state in the wake of a submerged obstacle. Bénard answers this question negatively, but his work dealt with whirls produced in a free surface. The present authors undertook to investigate the same phenomenon within a liquid mass.

To do this they have compared the flow characteristics of Liquid I, plain water, and of Liquid II, a solution of sugar in water, having different kinematic coefficients of viscosity but the same temperature. The obstacle used was a vertical cylinder 3.5 mm. in diameter, and from this test they came to the conclusion that the Reynolds similarity applies to the case of alternate whirls. Among other things, they have used an interesting method of observation which might be called that of luminous fringes. Small pieces of aluminum foil were immersed in the flowing water. These pieces act as little mirrors and appear brilliantly illuminated when the normal to the surface of the foil bisects the angle formed between the incident rays and the line from the foil to the observer's eye. Hence every time the small pieces of foil

in their movement become parallel to a given direction, they become brilliant. In this way luminous bands are obtained which can be observed by a stroboscopic method. The period of the whirls is measured by the shortest period of illumination for which the bands appear stationary. In this way it is found that much higher frequencies can be measured than by direct observation.

The initial experiments were made in a fairly small vessel and it was found that the action of the walls exerted an appreciable effect on the results obtained. A new series of experiments were

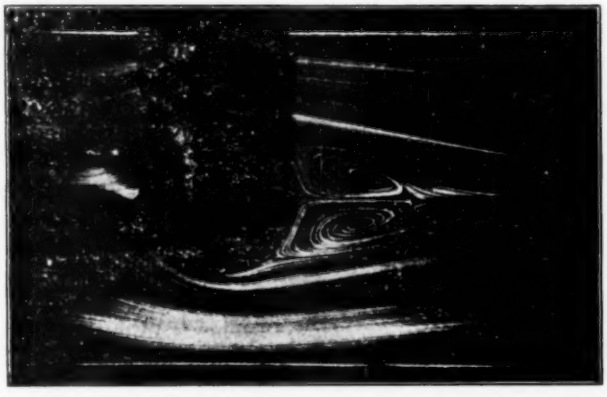

FIG. 5 WAKE OF A CYLINDER IN LAMINARY STATE IN OIL. α AND β CURVES

therefore undertaken where this factor was eliminated. In this series of experiments the diameters of the cylinders varied from 1.70 mm. to 11.90 mm.

In this case it was again found that the laws of dynamical similitude apply to the flow of the liquid. Further tests were then made to determine whether there was a unique critical number R_0 which would mark the beginning of the creation of a turbulent state in the wave of a submerged obstacle, that is, the distinct appearance of alternate whirls. When the obstacle is of a small diameter, the appearance of these whirls is manifested by the reaction exerted by them on the wake which first is rectilinear and then suddenly becomes undulatory. When however, the obstacles are of fairly large diameter, say, 10 mm. (0.4 in.), the period of transition corresponding to the passage from the Poiseuille state to a turbulent state is of appreciable length. This is easily explained, however, by the fact that the duration necessary for the establishment of a state must, according to the law of similitude, satisfy the equation

FIG. 6 SCHEMATIC VIEW OF SINGULAR-POINT CURVES α AND β

$$\frac{\theta_1}{\theta_2} = \frac{D_1^2}{D_2^2}$$

For obstacles from 1 to 10 mm. in diameter this ratio attains a value of 100. The critical velocities obtained experimentally for each obstacle as well as the knowledge of the viscosity of the liquid have permitted the authors to determine for each case the value corresponding to the Reynolds number R_0. They have therefore been able to establish that this number is unique and that under the conditions of their experiments, its value lies between 47 and 48, which corresponds to the Strouhal parameter $S_0 = 0.117$ (the Strouhal parameter being equal to D/VT).

In order to study the rise of the turbulent state a method was found by means of which, by the introduction of a whitish precipitate, it became possible to observe the various curves. The figures in the original article show the appearance of the wake during the Poiseuille state. As the speed increases, curves progressively appear, being shown by the precipitate continuously detached from the obstacle. When the turbulent state is attained, a rather complicated phenomenon takes place and a new permanent state is established which is characterized by a different system of curves analogous in general to the preceding one, but the curves are more extended. As the turbulent state is attained, there appear at the end of the α and β curves alternately on either side, small deformations of the lobes. These lobes show up more and more distinctly. The tail of the wake, which was in a motionless state until that time, begins to oscillate lightly, and the curves α and β become deformed more and more.

On the whole, the investigation would appear to indicate that alternate whirls present merely one aspect of a more general periodic phenomenon which exists from the beginning of the flow but does not appear clearly visible except under well-determined conditions defined by the value of the critical number. In this connection tests were made with the object of determining the coefficient of resistance of cylinders immersed in flowing water. The curves obtained, which represent a variation of resistance practically in a line function of velocity of flow, show also that this resistance does not undergo any sudden variation when the Poiseuille state changes to the turbulent state.

Among the general conclusions arrived at it is stated that the law of dynamical similitude of Osborne Reynolds applies to periods of formation of alternate whirls produced under the conditions defined above, and further that there is a unique Reynolds number R_0 for similar obstacles, this number indicating the appearance of clearly defined alternate whirls. The vibration of rods held at one end makes it possible to discover in the zone of velocities corresponding to the Poiseuille state a periodic phenomenon controlled by the same law that controls the alternate whirls. The Strouhal curve seems to pass through the origin and its shape does not reveal any particular feature indicating the passage from the Poiseuille state to the turbulent state. (P. Dupin and M. Teissie-Solier in *Révue Générale de l'Electricité*, vol. 24, no. 2, July 14, 1928, pp. 53 to 60, 10 figs., *e*)

NATIONAL DEFENSE

"The Frolicsome Battleship"

THIS is a continuation of an article, "The Battleship Bubble," abstracted in MECHANICAL ENGINEERING, September, 1928, page 713. In the present article the author attempts to prove that the battleship is essentially incapable of such rapid maneuvers as would permit it to dodge bombs dropped by aircraft.

The most modern American battleships are the *Maryland*, *Colorado*, and *West Virginia*, with a normal displacement of 32,600 tons, full load of 33,590 tons, length overall of 624 ft., beam or width of 97 ft. 3 1/2 in., and maximum draft of 31 ft. 7 in. In other words, in order that a battleship of the *Maryland* class may float upon the surface it must displace 33,590 tons of water—an area of water 600 ft. long, at the waterline, by 97 ft. wide, and 31 1/2 ft. deep. The underwater area of the hull is about 72,000 sq. ft.

This is a tremendous amount of water, and a tremendous area of steel surface which must be driven through the water. For as the ship proceeds for a distance of 600 ft. it must displace 33,590 tons of water ahead of it, while 33,590 tons of water close in behind it.

The battleship's speed varies from about 21 knots for such modern American vessels as the *California* and *Tennessee*, to 23 knots for the *Nelson* and *Rodney*, the latest British battleships. Battle cruisers, such as the British *Hood*, have of course a very much higher speed. The maneuverability of a battleship is, however, very low and, according to official data, a battleship will attain 12 knots from stopped in from seven to ten minutes, and by stopping her engine, a battleship takes about twenty minutes to reduce from 12 to 2 knots. According to the same official source (the British Admiralty's "Manual of Seamanship") a battleship at 21 knots with 35 deg. of helm will have that speed reduced to 47 per cent at 16 points. This means that when the battleship has turned a "right-about" her speed will be less than half what it was before she started the turn. The reason for this loss of speed in making a turn is as follows: A battleship of the size of the *Maryland*, as stated above, displaces 33,590 tons of water. When the ship is going straight ahead, the only resistance is due to the cross-section of her hull and the suction behind the stern, which is more or less streamlined. When the rudder is put hard over to starboard, the stern will be forced over to port, which requires water to be pushed out of the way; and the water will rush in on the starboard to take up the space of the water pushed out. Simultaneously, the starboard bow will push water out of the way; and the water will have to rush in on the port bow to take its place. Of course, this increases the ship's resistance to the water, for it throws one end of the ship one way, and the other, the other way; both the bow and the stern have to push water out of the way, and then have a suction on the other side against it to fill up the vacuum made by the turn. Consequently the ship is slowed down to less than half her straightway speed.

The remainder of the article is devoted to a discussion of the other difficulties of dodging a maneuver of battleships in line formation. The author cites examples which would illustrate that under this condition, practically no zig-zagging or change of formation is possible unless carried out very slowly and under the most favorable conditions. (Cy Caldwell in *Aero Digest*, vol. 13, no. 2, August, 1928, pp. 223–225 and 348, 350, 352, 354, and 356, *g*)

POWER-PLANT ENGINEERING (See also Fuels and Firing)

Electric Steam Generators

AT THE present price of coal, electric boilers can be operated economically only on secondary power. Secondary power might be defined as: (1) power that has been developed but not yet sold for commercial use; (2) off-peak power that cannot be marketed for commercial purposes. In the development of a hydroelectric plant the cost per kilowatt is often less if the entire plant is constructed at one time, rather than a part at a time to keep pace with the growth in load. If the cost per kilowatt is not too high the surplus power, if used for the generation of steam, will earn sufficient revenue to pay the fixed charges in the additional investment. Thus, if boiler load is available, a large generating station can be constructed, and fully loaded as soon as it is ready for operation.

On power systems depending only on water power it is necessary to limit the prime power sold to an amount corresponding to the minimum flow of the steam or streams. All power capable of being generated at any time above this amount may be sold as secondary power. Also, most power systems are subject to a considerable drop in load at night. The spare capacity available at such times can be made use of for the generation of steam.

The rate of which electric power must be sold to compete with coal is given by the formula

$$R = \frac{1.66C}{Be}$$

in which R is the rate in dollars per kilowatt-hour, C is the cost per short ton of coal delivered on the grates, B is the B.t.u. per lb. of coal, and e is the thermal efficiency of the coal-fired boilers.

The efficiency of the electric boiler is taken at 87 per cent in this formula.

With coal at $6.25 per ton, a heating value of 13,000 B.t.u. per lb. and a boiler efficiency of 78 per cent; the corresponding rate of electric power would be 1.02 mills per kilowatt-hour. (C. R. Reid, Shawinigan Water and Power Co., Committee Report to Canadian Electrical Association, abstracted through *The Electrical News*, vol. 37, no. 13, July 1, 1928, pp. 42–43, *p*)

The Padiham Power Station

THE Padiham (England) Station of the Lancashire Power Co. is a comparatively small unit. It is situated on the outskirts of the town of Padiham on the River Calder, and has been arranged for an ultimate plant capacity of 60,000 kw., of which about half has been actually installed. It is quite remarkable because of its thermal efficiency of 20.61 per cent as a year's average, and because of the fact that this efficiency has been attained not only in a comparatively small plant but in a plant of remarkably simple and cheap design. In most modern plants, as stated in an editorial in *The Engineer*, July 27, 1928, one may say broadly that greater efficiency has been sought by following theoretical considerations so far as the courage and the purse of their owners would allow.

Padiham was built on the idea that a higher and more consistent efficiency could be obtained by minimizing every possibility of trouble and loss rather than by resorting to special pressure, temperature, heat cycle, method of combustion, and the like.

It is not claimed, of course, that the use of higher pressures, temperatures, and special devices is wrong in itself. What Padiham has done is really to demonstrate the extraordinary potentialities of a simple plant. The design has been dominated by two considerations: First, to make continuous good operation as easy as it could possibly be made; and second, to eliminate every feature calling for an unwarranted degree of care and attention from the operating staff.

The ultimate boiler equipment will consist of sixteen boilers arranged in two boiler rooms side by side. At present only one boiler house is constructed containing six boilers—four on one side of the firing aisle and two on the other. The boilers are of the old Babcock & Wilcox stationary type, each with three longitudinal drums. The working pressure is no higher than 250 lb. per sq. in. and the temperature of the steam at the superheater outlet does not exceed about 620 deg. fahr. A rating of less than 3.8 lb. of steam per sq. ft. has been adopted, a recognition of the fact that easy steaming tends to efficient operation. Excellent lighting and ease of access and supervision are said to have been successfully achieved.

The engine room has two turbine units, each of 7500 kw. maximum continuous rating, and one of 15,625 kw. maximum continuous rating. The larger machine runs at 1500 r.p.m. and the two smaller machines at 3000 r.p.m. The auxiliary plant comprises three circulating pumps, each capable of dealing with one-third the water required by the two condensers. This arrangement permits the use of smaller and more efficient pumps than would otherwise be the case, and in the event of the breakdown of one circulating pump there still remain two-thirds of

the total pumping power available. Two of the pumps are driven by direct-current motors and the other by a variable-speed alternating-current commutator motor.

Steam is delivered to the main line at a gage pressure of 250 lb. per sq. in., and at a temperature of 620 deg. fahr. It expands in the main turbines to a vacuum usually between 29.3 in. and 29.4 in. The condensate, at a temperature in the neighborhood of 70 deg. fahr., is raised to about 120 deg. fahr. in a closed heater situated between the boiler feed pumps and the economizers. The heating is effected by exhaust steam at atmospheric pressure, coming from the Allen auxiliary engines which provide the auxiliary direct-current supply, and from the steam-driven boiler feed pumps. The amount of exhaust steam can be varied to suit the quantity of condensate at any time by changing over the auxiliary motors or station lighting from one system to another, or by running either the steam or the motor-driven feed pumps. The steam supply for the Allen reciprocating sets is taken from a separate main in which the temperature of the steam does not exceed about 500 deg. fahr. This steam is obtained by tapping the superheaters at intermediate points. There is no deaerating plant, the condensate leaving the condensers practically air-free and passing to a covered hotwell from the bottom of which it is drawn by the feed pumps. The hotwell is sealed by steam admitted above the surface of the water and escaping through a small vent hole. As the hotwell is at atmospheric pressure, and its temperature is only about 70 deg., there must, of necessity be an enormous preponderance of air in the vapor above it. It is found, nevertheless, by daily tests that the free oxygen in the feed does not exceed about 0.15 cc. per liter, a proportion as small as that usually obtained by a special deaerating plant. The explanation no doubt is the quiescence of the water in the hotwell and the fact of the inlet and outlet both being at the bottom prevent any aeration of the surface layer of water from affecting the main flow through the tank. The make-up water is not obtained by evaporation, but from the river, and is treated first by the lime and soda process, and then by the zeolite process before entering the system. Its ultimate condition is that of zero hardness and slight alkalinity. So thorough is the treatment that blowing down of the boilers only amounts to a few inches per month, and in spite of this they are kept so clean internally that a brushing out once a year is all the cleaning they need. There are indeed no mechanical tube cleaners at all in the station.

The results of operation for twelve months ending March 31, 1928, for five months from November 1, 1927, to March 31, 1928, and for one month, March, 1928, are given in a table in the original article. The figures are remarkable. The overall thermal efficiency is 19.82 on units delivered, or 20.61 on units generated based on a year's operation. These results are still more interesting when the cost of construction is considered, which in the case of Padiham is £12 7s. ($60) per kilowatt installed. It may be added that sufficient information is available to show that the efficiency figure is reliable and, for example, the heat value of the coal is given at 12,000 B.t.u. per lb.

As regards the quantity of steam per kilowatt-hour, the designer of the plant, Mr. Adams, adopted a practice which differs considerably from that generally followed. The condensate from the turbines is not metered, no meters having been found really satisfactory; but is calculated from the output of the machines and their known steam consumption at various loads. Every turbine is tested with great care once a month at three loads. The condensate is pased over the V-notch of a Lea recorder and the height of water above the notch read at intervals of one minute by means of a vernier scale. A complete test lasts about two hours. The results are plotted, and the Willans line so obtained is taken as the basis of the performance of the machine for the next four weeks. Known corrections are, of course, applied for variations of vacuum or steam conditions. The turbines act, therefore, in effect as calibrated steam meters. To avoid vitiation of the results by condenser leakage and incidentally to avoid boiler trouble from the same cause, the condensate is tested every morning by a Megger, the electrical resistance of the condensate being compared with that of pure distilled water. The test is simple, easily applied, and extremely sensitive. It is carried out in the laboratory of the station. In favor of the method of obtaining the steam consumption per kilowatt-hour of the station, it may be pointed out that when, as usual, the steam consumption of a turbine is a linear function of the load, it follows that, once the line is determined, one has merely to know the total output of the machine over a given time of running to obtain the total quantity of steam used. Irregularity of load during the period has no effect on the total steam consumption for a given output. Nevertheless, at Padiham the load, absolute condenser pressure, and temperature of steam, temperature of condensate, and inlet and outlet temperatures of circulating water are accurately logged every half hour. Besides the steam consumption of the turbines, there is, of course, that used by the reciprocating sets and by the boiler feed pumps to be taken into account, and this is obtained similarly from their output and their known performances.

It is believed at Padiham that this method of obtaining the steam consumption of the station is more accurate than by the use of meters unless the latter are under continual supervision, calibration, and repair. It also provides a check on the turbine performances. Those who would criticize it may be asked in which direction the error would lie. If more steam is used than that computed, then the boiler-house efficiency must be phenomenally high. If the error is in the other direction the turbine efficiencies become incredible. Taking the month of March, for example, it is, humanly speaking, certain that the coal per unit generated was 1.33 lb. only, and the thermal efficiency of the station 21.34 per cent. If more water than 10.51 lb. was used per unit generated, then the evaporation was higher than 7.91 lb. of water per pound of coal, and the boiler-house efficiency greater than 80.95 per cent. Another thing in favor of the accuracy of the results is their great consistency, month by month. The operating results for twelve consecutive months are now available and the uniformity is extraordinary. As the station has "run like a clock" from the day it was started, a consistency of performance was to be expected.

The exceptionally high efficiency of the Padiham station is due partly to the operation and maintenance of the plant, and partly to the equipment and layout of the station. The daily load factor is good, but the station is completely shut down from midday on Saturday until 6 a.m. the following Monday. The plant has, therefore, to bear all the losses resulting from shutting down and restarting the boilers once every week. The equipment of the engine room and boiler house is in no way remarkable.

Brick-set land-type boilers with external cast-iron economizers, a very moderate steam pressure and temperature, no forced draft, no air heaters, no evaporators, no deaerators, and comparatively few instruments for the control of the boilers make a picture of the boiler house common when power-station efficiencies were of the order of 10 per cent or so. The modern highly efficient turbines and the excellent vacuum obtained are, of course, advantages which the older power houses did not have, but when all allowances are made for the engine-room performance, it is a matter for contemplation that what without disrespect one may call so old-fashioned a boiler house as that of Padiham can beat that vast majority of modern boiler houses

in efficiency. That it does so will be evident from Table 1 which gives, not the result or a short test, but the average performance for twelve consecutive months. The fuel used is 1-in. dry slack, with a small proportion of $^3/_4$-in. washed slack, containing all the fines normal to such coal.

TABLE 1 PADIHAM BOILER-HOUSE HEAT BALANCE, YEAR ENDING MARCH, 1928

	B.t.u.	Per cent
Heat transferred to water	9,728	80.5
Heat lost due to evaporating moisture in coal	82	0.7
Heat lost in dry flue gases	946	7.8
Heat lost due to hydrogen	501	4.1
Heat lost due to combustible in ash	79	0.7
Heat lost due to heat of ashes	20	0.2
Heat lost due to radiation and unaccounted for	729	6.0
Heat in 1 lb. of coal as received	12,085	100.0

(*The Engineer*, vol. 146, nos. 3784–3785, July 20 and 27, 1928, pp. 56–58 and 82–83. Compare also editorial entitled "The Design of Power Stations" in the issue of July 27, pp. 93–94, *dA*)

The New Central Station at Ivry, France

THIS central station is owned by the Seine Electric Co., a subsidiary of the Paris Electric Co., and was built to supply electric energy to the Metropolitan Railways Co. of Paris which operates the subways in that city. As now installed the station has a capacity of 60,000 kw., but it was designed so that it could be enlarged to generate 150,000 kw.

The boiler plant consists of six Babcock & Wilcox boilers equipped with chain-grate stokers and two boilers of the same company designed for pulverized fuel. Each of the boilers is provided with a superheater divided into two groups of seamless steel tubes. They are also equipped with economizers and air preheaters. Very careful attention was devoted to the methods of measuring and controlling the operation of the boilers. Each boiler is provided with two electric pyrometers to indicate the steam temperature and a number of draft gages to show the partial vacuum of the gases on the stoker at the exit from the boiler, at the economizer, and at the base of the smokestack. The total power delivered at each instant by the plant is shown in the boiler room on an integrating wattmeter, which is really located in the power plant but has a distinct reading arrangement by which the reading is projected on a large screen placed in the boiler aisle.

The combustion in each boiler is regulated by a device having two pens, each of which traces a polar diagram on a single chart. One of these diagrams shows the volume of hot gases and the other that of the steam. By regulating the combustion in such a manner as to obtain a coincidence of these curves, a rate of combustion is obtained corresponding to the most advantageous percentage of CO_2. A further advantage of this apparatus is that it gives instantaneous readings. Two registering thermometers show respectively the temperature of the hot air blown in under the grates of the stoker, and the temperature of the gas at the base of the chimney.

In addition to this apparatus intended for the control of the individual boilers there are also several for purposes of general control. These are located in a gallery in the pump room in the wall separating this latter from the boiler room.

There are four groups of turbo-alternators, each comprising an Escher Wyss & Co. turbine running at 3000 r.p.m. with an admission pressure of 18 kg. per sq. cm. (256 lb. per sq. in.) and an admission temperature of 350 deg. cent. (662 deg. fahr.). The turbine is direct-connected to a three-phase alternator having a frequency of 50 cycles and terminal potential of 10,500 volts. Each alternator carries on the end of the shaft an exciter of 74 kw. capacity and 240 volts. The stators are star-wound. Some of the auxiliaries may be of interest. The deaerators are of the "Scam" contraflow type and consist of a cast-iron vessel in which a vacuum is established by means of an ejector. The central part of this vessel is provided with a bundle of horizontal tubes through which steam flows at a pressure of 0.4 kg. per sq. cm. (5.7 lb. per sq. in.) and also evaporation steam from special boilers. The upper part of the deaerators contains strainers which break up the water to be deaerated into a fine spray. The lower part of the vessel forms a reservoir and is provided with a float cock which controls the admission of water in accordance with the demand of the feed pumps.

The operation of this device is as follows: The water to be deaerated on arriving at the top of the apparatus is broken up into small drops which fall on staggered troughs. These drops coming into contact with the superheated tubes burst, and because of their extreme subdivision the gases which they contain are liberated and carried away. The temperature of water at the entrance to the deaerator is 35 deg. cent. (95 deg. fahr.) and the temperature at the exit is 65 deg. cent. (149 deg. fahr.). Eighty-five tons of water are handled per hour. The original article gives data of power and steam consumption of the various devices. The special boilers referred to above are the boilers which produce distilled water. They are heated by live steam.

No data are given as to the operation of the plant and its efficiencies. (L. Vellard in *Révue Générale de l'Electricité*, vol. 23, no. 26, June 30, 1928, pp. 1109–1130, 20 figs., *d*)

POWER TRANSMISSION

Correcting Power Factor With Capacitors in the Distribution Feeders

MOST power companies serving an industrial load are confronted with a low power factor situation. To impose a penalty on the consumers who are responsible for this condition is effective only as a disciplinary measure and many efforts have been made to neutralize this trouble in other ways. Sometimes this can be accomplished by the use of synchronous motors in the various industrial plants, but this cannot be done where the plants are already equipped with other kinds of motors and are not willing to change over. Such a condition was found to exist in Grey's Harbor County, Washington, where there are a number of mills cutting timber. Such mills in order to handle the heaviest load with comparative ease select a motor which is in excess of the requirements for normal operation. Induction motors seem to be peculiarly adapted to this particular kind of work and their application under these conditions naturally results in low power factor.

The operating conditions were such that something had to be done and a study was made of the comparative advantages and disadvantages of synchronous condensers and capacitors. The latter were selected and it is claimed that the plant has made a saving of 500,000 kw-hr. annually in feeder-line losses by installing capacitors, a saving which could not be made by the synchronous condenser. The installation of the capacitors proved to be quite an easy matter and by this means it became possible to maintain a better voltage on the feeders, since the higher power factor on these circuits has increased the range of the regulators. The following summary is made by the author, general superintendent of the Gray's Harbor Railway and Light Co., Aberdeen, Wash.

"Summarizing, we have made kilowatt-hour savings amounting to a return of 10.1 per cent on the total investment, increased the peak capacity of our generator by 1600 kw. (or 45.7 per cent over conditions prevailing a year ago), increased the capacity of all of the feeders on which the capacitors are installed, as well as relieved the load on our feeder voltage regulators (with the result of increased range of the regulators), and increased the voltage to the consumer which means higher bills with a more satisfied consumer due to the better operating conditions

resulting in increased output. Also, it is usually considered that the consumer should correct his own power factor and be given a bonus for so doing or else be penalized for not doing so; but ours is an excellent example of the profit to be gained by the central station in making this correction on the consumer's premises. The figures used in calculating corrected lagging reactive kva. and the unit cost of $0.005 per kw-hr. for energy saved in line losses are certainly conservative but at the same time show sufficient justification for the installation." (Wm. S. Hill in *General Electric Review*, vol. 31, no. 7, July, 1928, pp. 366–371, 7 figs., *dp*)

PUMPS

Characteristics of Centrifugal Oil Pumps

RECENTLY a movement has been growing to use centrifugal pumps on oil pipe lines and at refineries. Because they are quantity pumps and have such merits as low first cost, simplicity or operation, steady flow, and adaptability for direct connection to high-speed machinery, centrifugal pumps attract all industries which have to deal with pumping machinery, but whereas the efficiency of a properly designed centrifugal water pump runs very high, this efficiency decreases when the same pump is used in a viscous fluid.

When pumping oil it is evident that besides all the ordinary mechanical and hydraulic losses, for a viscous liquid a new loss enters which dominates all the others. This is the viscosity or the internal-resistance loss. The effect of viscosity is to decrease the head capacity and to increase the disk friction. This lowers the efficiency of the centrifugal pump correspondingly.

It is important to know the laws which govern the decrease in the head capacity and the increase of horsepower which affect the efficiency of the centrifugal pump. It is also important to know the limiting value of viscosity for each type and size of centrifugal pump at which it is practical to pump viscous oils. Moreover, as it is a comparatively easy matter to test a pump on water, it is of great advantage to have a method by which it is possible to predetermine what a centrifugal pump of known water characteristics will do when pumping a viscous oil.

By characteristics are meant the curves which show the relation between the capacity, head, efficiency, and power at a constant speed. These curves are usually obtained from an actual test, using water as pumping medium.

As the paper is not suitable for abstracting, only the conclusions are reported as follows:

1 It is possible to predetermine, with a sufficient degree of accuracy, the performance of a centrifugal oil pump by observing its characteristics as obtained on water.

2 The effect of the viscosity is to decrease the head-capacity and increase the power.

3 When the pump is working in viscous oil, the increase in horsepower is influenced mainly by the increase in the disk friction due to viscosity.

4 The head-capacity characteristic and the efficiency of a centrifugal pump as applied to viscous oils improve with the increase of the size of the pump.

5 The volumetric efficiency, particularly that of a low-specific-speed centrifugal pump, improves with the increase of the viscosity.

6 In a multi-stage pump the performance is improved because of the heating of the oil in the pump by losses. This is more noticeable in pumps of low specific speed.

7 It seems that an impeller with "flat" characteristics will be more efficient when pumping viscous oils than an impeller with "steep" characteristics. (Michael E. Aisenstein, Hydraulic Engineer, Byron Jackson Pump Co., Berkeley, Calif., in *Proceedings of the American Society of Civil Engineers*, vol. 54, no. 6, Part 1, August, 1928, pp. 1709–1723, 9 figs., *tmA*)

The Friberg Vacuum Pump

THIS pump has been already adopted to some extent in the Scandinavian countries for drying timber and albuminous substances in vacuum and is claimed to produce a vacuum of from 99.7 to 99.9 per cent of the theoretically perfect.

In the attainment of a high vacuum by means of a reciprocating pump, one of the chief difficulties is, of course, the complete discharge of the contents of the pump cylinder at the end of the compression stroke, so that there shall be no remnant of gas left within to re-expand on the outward stroke and impede suction from the already partly evacuated space. For this reason the clearance between the piston and the cylinder head is always reduced to a minimum, but Mr. Friberg has gone even beyond this and made the clearance space a negative amount. In other words, the piston overruns the end of the cylinder, and lifts the cover with it at the end of the stroke. The top of the piston and the bottom of the cover are quite flat, and consequently no gas can remain in the cylinder.

On reference to the diagrams it will be seen that the cover is hollow, and is provided at the center with a spring-loaded suction valve *A*. Above the cylinder there is a camshaft *B*, driven from the pump crankshaft, for operating the suction valve and the rocking lever *C*. This lever is held down by a spring, as shown, and bears on the top of the cylinder cover.

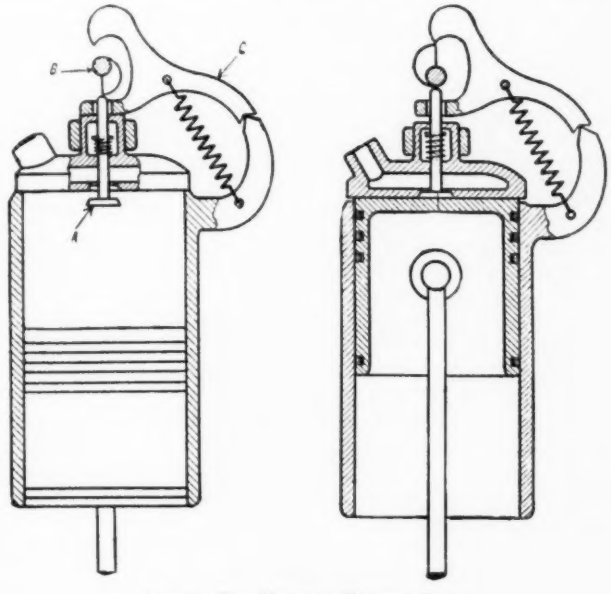

FIG. 7 THE FRIBERG VACUUM PUMP

The operation of the pump is, as follows: During the suction stroke, as shown in Fig. 7, the cam holds the suction valve open while the spring and rocking lever keep the cover in intimate contact with the machined end of the cylinder. Immediately the suction stroke has been completed, the cam allows the valve to close abruptly and compression of the charge starts. Toward the end of this stroke (see Fig. 7) the cam meets the upper projection of the rocking lever and lifts it against the resistance of the springs, so that the cover is free to rise with the piston and the contents are discharged through the space between the cover and cylinder end. On account of the movement of the cylinder cover it is, of course, necessary to make the connections with the space to be evacuated by means of flexible piping,

but this is said not to have been the source of any great trouble. (*The Engineer*, vol. 146, no. 3785, July 27, 1928, p. 97, 1 fig., *d*)

Characteristic Laws for a Centrifugal Pump With Fluids Other Than Water

THE AUTHOR tries to establish the relations between resistances and speeds of two centrifugal pumps operating under similar conditions, but with different fluids. He derives an equation connecting head, quantity, speed, and viscosity.

The author also made a series of tests at the University of Liverpool with a pump driven by a motor acting also as a transmission dynamometer. The experiments demonstrate that for practical purposes there is no difference between the head-quantity characteristics for water and other fluids unless the kinematic viscosities of these are many times that of water—in this pump at least 30 times—but the power required increases as the viscosity increases. With fluids of greater viscosity the head at a given number of revolutions per minute with the delivery valve closed is slightly greater than that obtained with water, but as the valve is opened the head rapidly falls below that given by water for the same delivery. At certain deliveries the pump becomes unsteady and there is a discontinuity in the characteristics. The kinematic viscosities of these fluids are so high that ν/vp (ν is kinematic viscosity, v the velocity of the pump, and p the wetted perimeter) corresponds to streamline motion at many sections in the path of the fluid, and the erratic behavior of the pump may be due to attempts to change from streamline to turbulent motion and vice versa. The variation of velocity across the passages also becomes large, and this probably helps to set up eddy motion and cause instability. There are three types of characteristics, one agreeing with those for water, one for small deliveries with fluids of high viscosity, and another with larger deliveries and viscosities, an unstable region occurring between the latter types. The disk friction and the combined eddy, circulation, and short-circuit losses increase as the viscosity increases. The latter, which are relatively large in a small pump like the one tested, make it impossible to apply the law of proportionality.

It was pointed out to the author that the discontinuity in the curves may be due to cavitation in the pump. In such an instance the effect would be due to volatility rather than viscosity. Separate tests, however, showed water and the less viscous oils to be more volatile than the more viscous ones. (Hubert Mawson in *Proceedings of the Institution of Mechanical Engineers*, 1927, vol. 2, pp. 1037–1045, 5 figs., *de*)

Submerged-Motor Pumps

OF LATE years, submerged-motor pumps have come to be widely used. With the present development of the squirrel-cage motor and with modern insulating methods and materials, difficulties of an electrical nature no longer form an important consideration. The problem of positively sealing the rotor shaft where it passes through the housing has also been solved in several ways. One such seal is shown diagrammatically in Fig. 8. A ring or collar *a*, closely fitting the motor shaft and revolving with it, but capable of axial movement, is located upon the end of the shaft which faces the pump, where it is kept lightly pressed against the end of the motor housing by means of a coil spring. By this arrangement the entrance of the liquid is rendered very difficult, no matter whether the motor is running or standing still.

The regulator *b* may in principle be considered as placed beside the motor, and therefore submerged to about the same depth. It has a control membrane *c* which is acted upon by three different forces, namely, the pressure of the small coil spring *d* and the

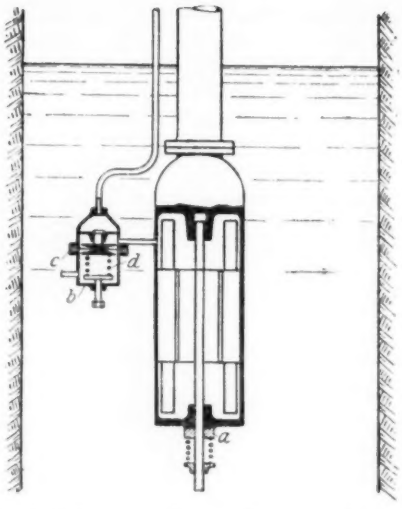

FIG. 8 STUFFING BOX AND EXCESS-PRESSURE REGULATOR OF A SUBMERGED-MOTOR PUMP

(*a* sealing collar; *b* regulator; *c* control membrane; *d* spring for regulating pressure in motor.)

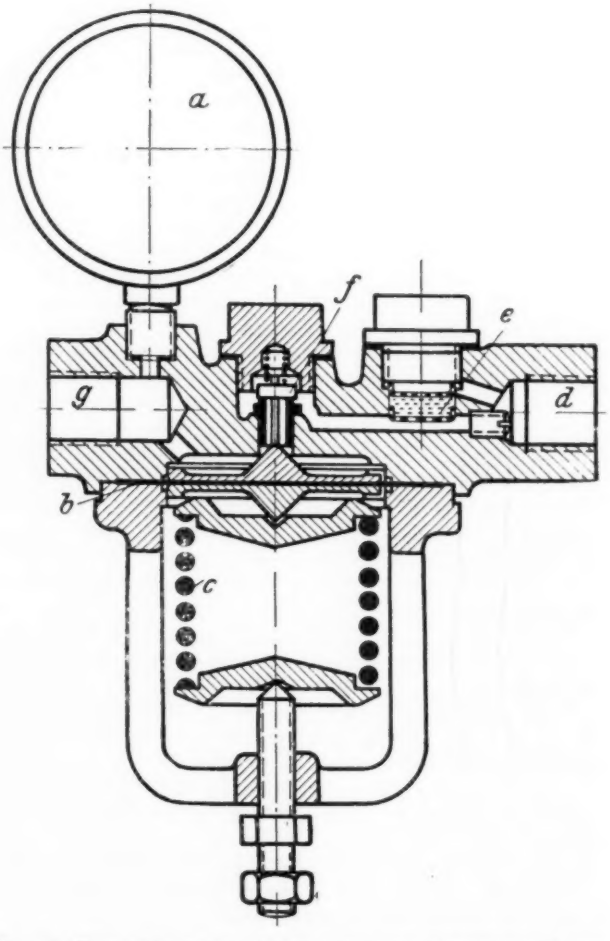

FIG. 9 EXCESS-PRESSURE REGULATOR FOR CONSTANT WATER LEVEL

(*a* manometer; *b* membrane; *c* adjusting spring; *d* high-pressure-line connection; *e* filter; *f* reducing valve; *g* motor connection.)

static pressure of the liquid upon the plunger on one side, and the pressure obtaining in the interior of the motor on the other.

The regulator serves to reduce the pressure of the gas—usually air—introduced into the motor housing under high pressure by way of a pipe, to a point corresponding to the equilibrium of the three forces referred to.

The fluctuations of the liquid level have the effect of so influencing the membrane as to cause the internal to exceed the external pressure by a predeterminable small amount. The excess internal pressure is removed by the escape of air along the shaft, the ring *a* being slightly forced away and thus acting as a relief valve.

The pressures from both sides upon the effective surfaces of the ring *a* are thus constantly kept very nearly balanced, so that the ring is practically under no load other than a slight pressure upon the cheek of the housing. This remaining pressure can be regulated by the choice and adjustment of the springs of the regulator and of the collar *a*. It will be seen that, owing to the absence of any noticeable thrust, wear on a stuffing box—if it can be so called—of this type is negligible, while on the other hand the ring, running continually in the liquid which is being pumped, is most efficiently cooled.

The regulator may be placed near the motor at about the height of the stuffing box, but there are certain disadvantages in such an arrangement. Because of this, a type of regulator has been developed which is placed above the ground.

In another type of pump shown in the original article, the motor is connected to the other parts by its lower flange. This construction permits the motor to expand lengthwise should it become heated. In this case the bell forms an integral part of the pump casing, but in another design it is placed below the pump. The discharge pipe is usually used for suspending the unit. These discharge pipes may be cast of various cross-sections, while in wells of large size, ordinary steel pipes may be used. In one design illustrated in the original article, a steel jacket around the pump is used to convey the water discharge. This construction is intended for wells of an especially small diameter or when a low water level and consequent greater heating of the motor have to be taken into consideration. Where liquids have to be raised from an unusually great depth, the diameter of the well is apt to be very small. In such cases even a steel jacket no longer answers the demands of economy in space, and it becomes necessary to place the motor below the pump, in which case the liquid is sucked in through the slit-like openings in the middle of the cylinder. If conditions are such as to render a drop of water level unlikely even while pumping to full capacity, the use of the bell becomes superfluous. A regulator designed for this condition is shown in Fig. 9. The constant pressure of the spring *c* takes the place of the pressure in the bell. By properly regulating the internal and external pressures, the consumption of air by the motors can be kept down to a very low figure. An automatic pressure system has been also designed. (H. Sauveur in *Engineering Progress*, vol. 9, no. 7, July, 1928, pp. 191–194, 11 figs., *d*)

SPECIAL CONSTRUCTIONS

The Concentric-Arch Dam

WHAT is said to be a new type of dam has been developed in France; it consists of two or more substantially concentric arches (Fig. 10). These arches are of different heights, the upstream arch being the higher and those further downstream being lower, step-wise. The space between the individual arches is filled with water to the top of the lower arch when the reservoir is full. The individual arches are entirely separate from each other except at the abutments.

The figure at the right-hand corner is a vertical cross-section through the dam. The water in the basins between the individual arches exerts a pressure upon both arches forming the basin, thus loading the downstream arch by radial pressure upon its extrados but relieving the upstream arch by the same amount of load. For instance, there is exerted upon arch 1 on the upstream face the pressure of the full head of water in the reservoir. Upon the downstream face of this arch acts the back-pressure in the first basin. Consequently, the resulting net water pressure to be carried by arch 1 is that represented by the area W_1 in the load diagram shown in the center of Fig. 10. Similarly, the arch 2 is subjected to the load W_2, and the arch 3 to the load W_3. Of course, it is necessary that the basins between the individual arches be always filled to the necessary elevation, especially when the reservoir is full. This can easily be effected by automatically controlled valves.

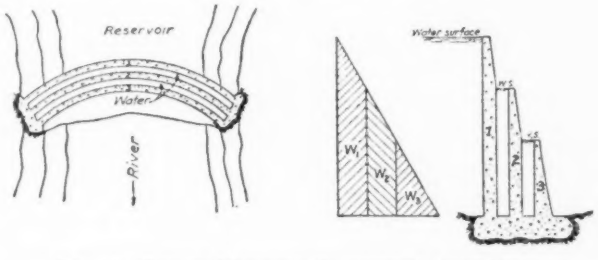

FIG. 10 FRENCH MULTIPLE CONCENTRIC-ARCH DAM

Theoretically, concentric arches are more efficient than a single arch of the same thickness as the separate arches taken together, because each one of the small arches approaches the dimensions of a "thin" arch for which the stresses from rib shortening and temperature are relatively much smaller than in a thick arch. A dam of the type described is under construction at Marège in the canyon of the Dordogne River in France. This dam is to consist of five thin arches of reinforced concrete placed one behind the other. The article describes tests carried out on a model of the dam. The French engineers have estimated that in some cases a saving in the quantity of concrete would amount to 20 or even 30 per cent over the quantities required by an ordinary type of arch dam.

For conditions in this country it might be preferable to build the several arches tightly one against the other, and merely separate them by painting the surface of one arch with asphalt, thus permitting the minute relative movements between the arches to take place when the load or temperature of the dam changes. The individual arches will then act as arch and cantilever laminas similarly, for instance, as in the case of laminated springs.

Preliminary designs have been made of several proposed arch dams, involving the feature of having one asphalted joint in the dam from the foundation up for about two-thirds of the height of the structure. Based upon the Cain theory, it is indicated that this arrangement will give in many cases, a better distribution of the stresses in a dam than without the joint. (Fred A. Noetzli, Consulting Engineer, Los Angeles, Calif. in *Western Construction News*, vol. 3, no. 14, July 25, 1928, p. 465, 1 fig., *d*)

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general; *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society.

Instruments and Apparatus

Preliminary Draft of Part 3, Temperature Measurement, Chapter 7—Pressure Gage Thermometers

The Main Committee on Power Test Codes takes pleasure in presenting to the members of the Society for criticism and comment, Chapter 7 of Part 3 of Instruments and Apparatus dealing with Pressure Gage Thermometers. The Individual Committee which developed this draft consists of Messrs. C. F. Hirshfeld, Chairman, W. A. Carter, Secretary, C. M. Allen, E. G. Bailey, L. J. Briggs, C. R. Cary, J. D. Davis, R. E. Dillon, F. M. Farmer, J. B. Grumbein, W. H. Kenerson, E. S. Lee, O. Monnett, S. A. Moss, R. J. S. Pigott, and E. B. Ricketts.

Code No. 19 on Instruments and Apparatus will consist of twenty-two parts dealing with the following subjects: (1) General Considerations,[1] (2) Pressure Measurement (6 chapters),[2] (3) Temperature Measurement (11 chapters),[3] (4) Head Measurement, (5) Measurement of Quantity of Material, (6) Electrical Measurements, (7) Mechanical Power, (8) Measurement of Indicated Horsepower, (9) Heat of Combustion, (10) Chemical Composition, (11) Quality of Steam, (12) Time Measurements, (13) Speed Measurements, (14) Mechanical Measurements, (15) Surface Area, (16) Density, (17) Viscosity Measurements, (18) Humidity, (19) Concentration of Dilute Solutions, (20) Smoke, (21) Leakage Measurements (2 chapters),[4] and (22) Hydraulic Power Plants.

Complete copy of the draft which is published here in abstract may be obtained from the Society's headquarters. The Individual Committee, the Main Committee, and the Society will welcome suggestions for corrections or additions to this draft from those who are especially interested in this subject. These comments should be addressed to the Chairman of the Committee in care of The American Society of Mechanical Engineers, 29 West 39th Street, New York, N. Y.

General

1 Pressure gage thermometers may be divided into three classes, depending upon the method by which the actuating force is obtained. Class 1 thermometers utilize the direct expansion of a liquid to move the pointer or pen arm of the instrument, and are generally known as liquid-filled pressure gage thermometers. Class 2 thermometers utilize the changes in the pressure of the saturated vapor of a fluid with changes in temperature to move the pointer or pen arm of the instrument. They are generally designated as vapor-pressure or vapor-tension pressure gage thermometers. Class 3 thermometers utilize the direct expansion of a gas to move the pointer or pen arm of the instrument and are generally known as gas-filled pressure gage thermometers.

2 The essential parts of thermometers of the three classes are practically the same, the differences being principally in the fluid used in them. In each kind of thermometer the main parts are: (*a*) the bulb, which usually contains most of the fluid, and which is immersed in the medium, whose temperature is being measured; (*b*) the pressure gage, which includes the pointer or the pen arm which is moved under the influence of the changes of pressure within the bulb; and (*c*) the capillary tubing which connects the bulb with the actuating device of the pressure gage. These parts are described in detail under "Description," Pars. 19 to 37, inclusive.

Class 1—Liquid-Filled Thermometers

3 The component parts of a liquid-filled pressure gage thermometer are shown in Fig. 1. The system is completely filled

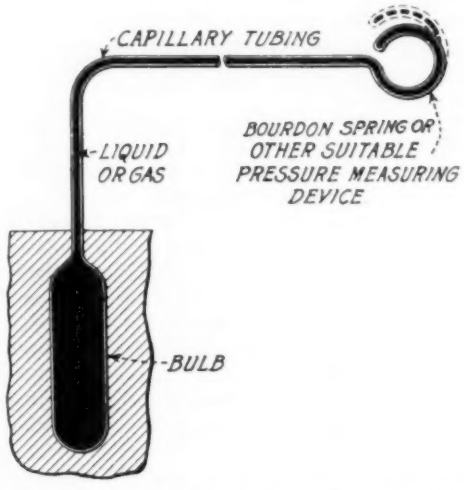

Fig. 1 Elements of a Liquid-Filled Pressure Gage Thermometer

with a liquid. When heat is applied to the bulb of such a system the liquid expands, exerting a pressure in the Bourdon spring of the gage, which tends to take the shape shown by the dotted lines in Fig. 1. The pointer or pen arm of the pressure gage, which is operated through a multiplying linkage system by the movement of the end of the Bourdon spring, moves over a scale that is calibrated to read directly in temperature.

4 *Liquids Used.* The liquids most commonly used in such thermometers, with their working ranges, are as follows:

Mercury is frequently used because of its wide temperature range: —38 to 1000 deg. fahr. Its coefficient of expansion is low

Alcohol is used between the temperatures of —50 and 300 deg. fahr.

5 *Advantages.* The chief advantage of the Class 1 thermometers is that they have uniform scales (i.e., the divisions in each particular scale are of uniform size). They are primarily suited to applications requiring a small bulb and short capillary tubing.

6 *Disadvantages.* Thermometers of this type are subject to errors resulting from the capillary tubing being at a different temperature while in service from what it is during calibration. The magnitude of such errors depends upon several things: namely, (*a*) the ratio of the amount of expanding liquid in the tubing to that in the bulb and to the increase in volume of the spring; (*b*) the difference between the temperature of the bulb, tubing,

[1] This Part was published in the February, 1923, issue of Mechanical Engineering.

[2] Chapter 1 of Part 2, on Barometers, was published in the November, 1927, issue of Mechanical Engineering.

Chapter 6 of Part 2, on Tables, Multipliers and Standards for Barometers, Mercury and Water Columns and Pressure Measurements, was published in the July, 1928, issue of Mechanical Engineering.

[3] Chapter 1 of Part 3, General, was published in the December, 1925, issue of Mechanical Engineering.

Chapter 6 of Part 3, Glass Thermometers, was published in the April and May, 1926, issues of Mechanical Engineering.

[4] Chapter 1 of Part 21, on Condenser Leakage Tests, was published in the November 1925, issue of Mechanical Engineering.

and spring; and (c) the difference between the temperature of the tubing and spring during calibration and while in service. In one case the error in the indication of a mercury-filled thermometer of this type amounted to 75 deg. fahr. when measuring the temperature of flue gas at 600 deg. fahr. This error was due solely to the fact that about 25 ft. of capillary tubing was resting against a hot boiler wall during service, and it was therefore at a

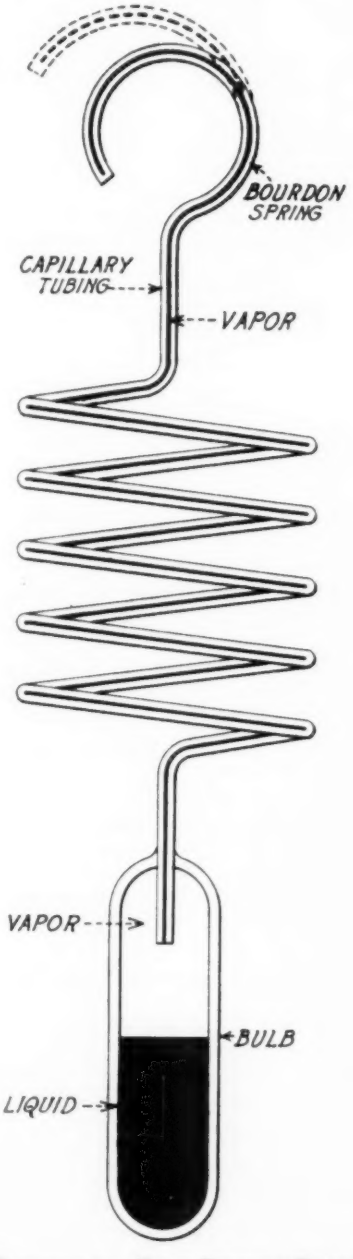

FIG. 2 ELEMENTS OF A VAPOR-PRESSURE THERMOMETER

higher temperature in service than during calibration. This effect is usually minimized in instruments in which the ratio of the volume of the bulb and the increase in volume of the spring to that of the capillary tubing is large.

7 Under similar conditions the time lag of liquid-filled thermometers is greater and the sensitivity is less than with Class 2 thermometers.

8 The length of the capillary tubing is limited to approximately 25 ft. unless special precaution is taken, and it is recommended that if possible the installation be made with a shorter length. Commonly the length of tubing is about 10 ft.

CLASS 2—VAPOR-PRESSURE THERMOMETERS

9 The action of the vapor-pressure thermometer depends upon the fact that the pressure inside the thermometer is determined by the temperature of the free surface of the liquid. In this type of thermometer, when all the parts are at the same temperature and in the position shown in Fig. 2, the bulb is about three-fourths filled with liquid, the remainder of the bulb along with the capillary tubing and the Bourdon spring being filled with the vapor of that liquid. Before sealing the bulb-and-tube system during its manufacture the system is carefully freed of air, so that the pressure on the surface of the liquid is only that of the saturated vapor at the temperature of the bulb. Fig. 2 shows the essential features of a thermometer of this type. In some cases the only part of the bulb, capillary tubing, and spring system not filled with liquid is a small part of the spring.

10 If the capillary tubing and pressure gage contain only vapor, the indications of the instrument are not subject to error due to variation of the temperature of the tubing. When installing an instrument of this type special precautions should be taken to insure that the gage and tubing are arranged properly. See "Installation," Pars. 42 to 51.

11 *Liquids Used.* The liquids used in Class 2 thermometers, with their boiling points for atmospheric pressure, their critical temperatures, and their critical pressures are given in Table 1.

TABLE 1 BOILING POINTS, CRITICAL TEMPERATURES, AND CRITICAL PRESSURES OF LIQUIDS FOR PRESSURE GAGE THERMOMETERS

Liquid	Boiling point, deg. fahr.	Critical temperature, deg. fahr.	Critical pressure, lb. per sq. in.
Ethyl alcohol	172.9	470	925
Benzene	176	550	705
Water	212	705.2	3197
Toluene	230.5	609	614
Aniline	363	799	764
Sulphur dioxide	14	311	1160
Ether	95	387	530
Methyl ether	−29	233	838

12 *Advantages.* The advantages of the vapor-pressure thermometer are that it is not subject to error as a result of variation of the temperature of the capillary tubing when the instrument is properly installed; the tubing need not be so small as that used for Class 1 thermometers; and any length of capillary tubing up to 200 ft. may be used.

13 *Disadvantages.* The principal disadvantage of the vapor-pressure thermometer is that the bulb temperature must be always above or always below temperature at case or along tubing, or error due to elevation of bulb above or below case will be variable.[5]

CLASS 3—GAS-FILLED THERMOMETERS

14 The component parts and the action of a gas-filled pressure gage thermometer are the same as those of a liquid-filled thermometer, shown in Fig. 1, except for the fluid used. In Class 3 thermometers, the system is completely filled with a gas. Changes in temperature at the bulb cause corresponding changes in pressure due to the expansion or contraction of the gas.

[5] The error resulting when the atmospheric pressure surrounding Class 2 instruments varies as much as it would between sea-level conditions and those obtaining at an elevation of 10,000 ft. above sea level, would be from 1 to 13 deg. fahr., depending upon the range of the instrument, the part of the range under observation, and the kind of material with which the instrument system is filled. The error will be greatest when the instrument is indicating temperatures near the lower end of its range.

15 *Gas Used.* Nitrogen is the gas most commonly used in Class 3 thermometers. It can be used between —60 and 1000 deg. fahr.

16 *Advantages.* The chief advantages of the Class 3 thermometers are that they have uniform chart scales and that they have a wider range. With large bulbs, any length of capillary tubing up to 500 ft. may be used.

17 *Disadvantages.* Thermometers of this type are subject to errors resulting from the capillary tubing being at a different temperature while in service from what it is during calibration. However, the ratio of the volume of gas in the bulb to that in the spring and capillary tubing is sufficient to minimize this effect.

18 Under similar conditions, the sensitivity of gas-filled thermometers is less than with Class 2 thermometers.

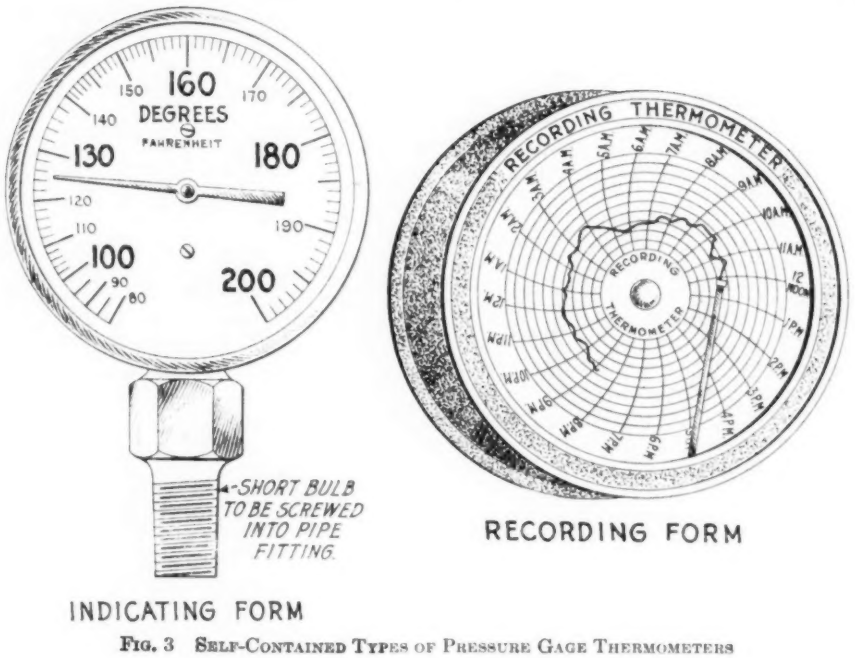

Fig. 3 Self-Contained Types of Pressure Gage Thermometers

Description

19 Pressure gage thermometers may be of either the self-contained or extension type. A thermometer of the self-contained type has the entire working element, including the bulb, closely and rigidly assembled as a unit, while a thermometer of the extension type has the bulb connected to the pressure-measuring mechanism by a long capillary tubing, thereby making it possible to install them at widely separated locations. Thermometers of either type can be obtained in two

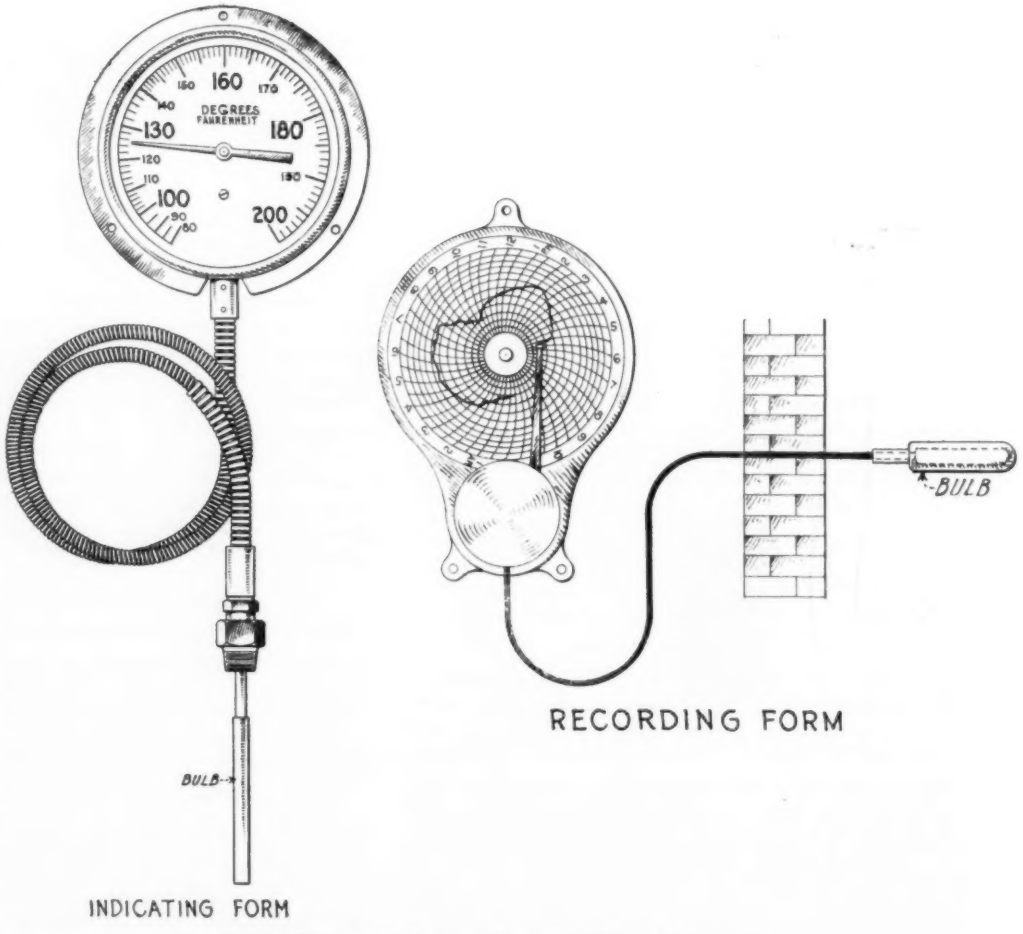

Fig. 4 Extension Types of Pressure Gage Thermometers

forms, namely, the indicating form and the recording form. The term "index thermometer" is often applied to pressure gage thermometers of the indicating form. Fig. 3 shows an indicating and a recording self-contained thermometer. Extension-type thermometers of the indicating and recording forms are shown in Fig. 4.

RANGE AND ACCURACY BOTH INDICATING AND RECORDING

38 Class 1 Thermometers:

Liquid used	Range, deg. fahr.	Limits of error, deg. fahr.
Mercury	—38 to 1000	2 to 10
Water	200 to 500	2 to 10
Alcohol	—50 to 400	2 to 10
Class 2 Thermometers:		
Vapor used		
Alcohol (ethyl)	200 to 400	2 to 10
Benzene	200 to 500	2 to 10
Water	250 to 600	2 to 10
Toluene	250 to 500	2 to 10
Aniline	400 to 700	2 to 10
Sulphur dioxide	20 to 250	2 to 10
Ether	100 to 300	2 to 10
Methyl ether	—20 to 200	2 to 10
Class 3 Thermometers:		
Gas used		
Nitrogen	—60 to 1000	2 to 10

INSTALLATION

(See "General—Installation," Pars. 15 to 24, Part 3, Chapter 1.)

39 When installing a vapor-pressure temperature recorder the variation in reading due to the change in temperature of the recorder itself may be overcome by enclosing the recorder in a glass-front case in which the temperature is thermostatically controlled at a point slightly above the highest temperature likely to obtain in the room. This constant temperature may be maintained by an electric lamp cut in and out by the thermostat.

40 When installing a thermometer of this type the bulb and such part of the capillary tubing as was immersed during calibration should be immersed to the same point.

41 If the installation is made in such a manner that the temperature of the capillary tubing is different during service and during calibration, an error will result with Class 1 and Class 3 thermometers and it may or may not result with Class 2 thermometers, depending upon whether the capillary tubing is filled with liquid or vapor, or contains both. With Class 1 and Class 3 thermometers the magnitude of the error will depend upon the temperature difference during calibration and service, and upon the portion of the liquid within the system that is within the capillary tubing. With vapor-pressure (Class 2) thermometers the magnitude of the error depends upon several different factors which are discussed under separate cases in the following paragraphs.

42 The results obtained with vapor-pressure thermometers are so affected by the arrangement of the installation that several cases are to be considered. It is assumed that the liquid in the system may shift back and forth between the bulb and capillary tubing, depending upon the way it is carried and handled during installation. The cases to be considered may be described as follows:

CASE 1—Bulb higher than pressure gage and hotter than capillary tubing. All of liquid in bulb when instrument is installed. [See Fig. 12(*a*).]

CASE 2—Same as Case 1 except that part of the liquid is in the capillary tubing and spring.

CASE 3—Bulb higher than pressure gage and colder than capillary tubing. All of liquid in bulb when instrument is installed. [See Fig. 12(*b*).]

CASE 4—Same as Case 3 except that part of the liquid is in the capillary tubing and spring.

CASE 5—Bulb lower than pressure gage and hotter than capillary tubing. All of liquid in bulb when instrument is installed. [See Fig. 12(*c*).]

CASE 6—Same as Case 5 except that part of the liquid is in the capillary tubing and spring.

CASE 7—Bulb lower than pressure gage and colder than capillary tubing. All of liquid in bulb when instrument is installed. [See Fig. 12(*d*).]

CASE 8—Same as Case 5 except that part of the liquid is in the capillary tubing and spring.

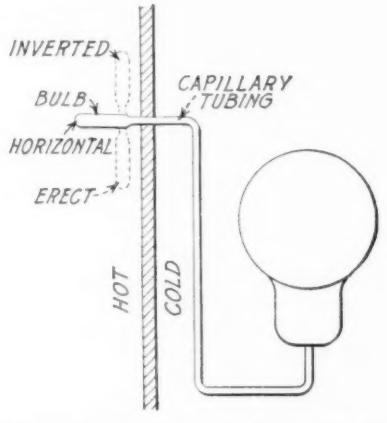

FIG. 12(*a*) METHODS OF INSTALLATION FOR CASES 1 AND 2—BULB HIGHER THAN PRESSURE GAGE AND HOTTER THAN CAPILLARY TUBING

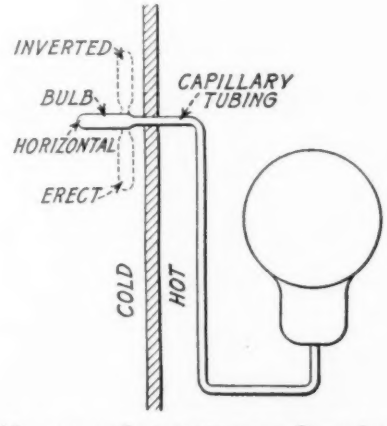

FIG. 12(*b*) METHODS OF INSTALLATION FOR CASES 3 AND 4—BULB HIGHER THAN PRESSURE GAGE AND COLDER THAN CAPILLARY TUBING

In discussing the conditions encountered and their effects upon the temperature indicated in each case, several assumptions are made: namely,

(*a*) The instrument was calibrated with the bulb and pressure gage in the same relative position as during service.

(*b*) The instrument maker put such an amount of liquid within the instrument that with all of the liquid within the bulb, or with the pressure gage and capillary tubing completely filled with the liquid, the free surface of the liquid will be within the bulb when the bulb is subjected to temperatures within the range of the instrument and when the capillary tubing is subjected to the temperatures intended when the instrument was constructed.

(*c*) During the calibration of the instrument the capillary tubing was at the temperature contemplated when the instrument was constructed, and the bulb was at a higher or lower temperature as mentioned in the case under consideration.

(*d*) When the thermometer was installed in the calibrating bath the liquid was in the coldest part of the system, and the bulb was in a vertical position with the capillary tubing connection at the top of the bulb (erect position).

(*e*) The exposed end of the capillary tubing that extends into the bulb is so placed that no matter what the position of the bulb, this exposed end will always be submerged, or sealed, in the liquid.

43 CASE 1. When a vapor-pressure thermometer is installed under such conditions, the capillary tubing, the pressure gage, and a part of the bulb will be filled with vapor. As soon as the temperature of the bulb becomes greater than that of the tubing, liquid will be forced through the capillary tubing, completely filling the tubing and the pressure gage. The pressure at the gage will correspond to the temperature of the bulb, except for the increase in the pressure at the gage due to the head of the liquid above it. There will therefore be an error in the indication of the instrument, resulting from the variation of the hydrostatic pressure upon the gage due to the variation in the weight of the unbalanced column of liquid above the level of the center of the pressure gage with variations in the temperature of the capillary tubing. This error can be reduced to a minimum by having the temperature of the capillary tubing at the time of calibration as near the same as that during service as possible. The position of the bulb (horizontal, inclined, upright, or inverted) has no effect upon the temperature indicated.

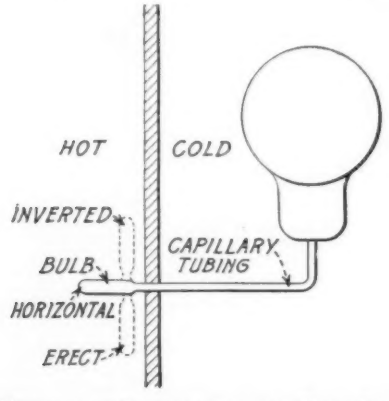

FIG. 12(*c*) METHODS OF INSTALLATION FOR CASES 5 AND 6—BULB LOWER THAN PRESSURE GAGE AND HOTTER THAN CAPILLARY TUBING

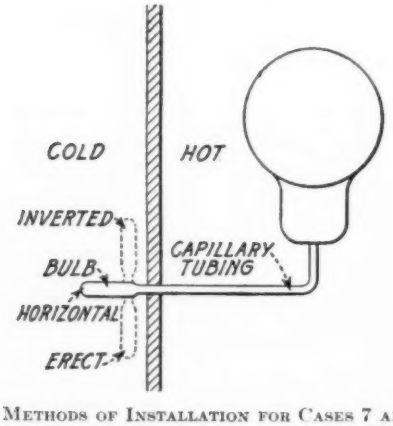

FIG. 12(*d*) METHODS OF INSTALLATION FOR CASES 7 AND 8—BULB LOWER THAN PRESSURE GAGE AND COLDER THAN CAPILLARY TUBING

44 CASE 2. This case differs from Case 1 in that it does not take as long for the capillary tubing and pressure gage to become completely filled with liquid.

45 CASE 3. If the bulb of the instrument is installed in an erect position, the liquid will remain within the bulb and the vapor within the capillary tubing will be superheated without affecting its pressure. The temperature indications will be correct and they will not be affected by variation in the temperature of the tubing. If the bulb is installed in a horizontal or an inverted position, some of the liquid will run out of the bulb into the tubing, there to be vaporized. This vapor will flow into the bulb where it will be condensed and started over on the same cycle. The pressure within the system neglecting hydrostatic pressure will correspond to the temperature within the tubing at the point where vaporization takes place and not to the temperature of the bulb.

46 CASE 4. This case differs from Case 3 in that with the bulb in an erect position, time must be allowed for the liquid in the tubing and gage to vaporize and then condense in the bulb, after which the same conditions will obtain as in the first part of Case 3.

47 CASE 5. When a thermometer is installed under such conditions, the capillary tubing, the pressure gage, and a part of the bulb will be filled with vapor. As soon as the temperature of the bulb exceeds that of the tubing, liquid will be forced through the capillary tubing, completely filling the tubing and the gage. This pressure at the pressure gage will correspond to the temperature of the bulb, except for the reduced pressure at the gage, due to the column of liquid between the bulb and the gage. There will therefore be an error in the indications of the instrument resulting from the variation of the hydrostatic pressure upon the gage due to variations in the weight of the column of liquid above the level of the liquid within the bulb, with variations in the temperature of the capillary tubing. This error can be reduced to a minimum by having the temperature of the tubing at the time of the calibration of the instrument as near the same as that during service as possible. The position of the bulb (horizontal, inclined, upright, or inverted) has no effect upon the temperature indicated.[6]

48 CASE 6. This case differs from Case 5 in that it does not take as long for the capillary tubing and pressure gage to become filled with liquid.

49 CASE 7. If the bulb of the instrument is installed in an erect position, the liquid will remain in the bulb and the vapor within the capillary tubing will be superheated without affecting its pressure. The temperature indications will be correct and they will not be affected by variations in the temperature of the tubing. If the bulb is installed in a horizontal or an inverted position, some of the liquid will run out of the bulb into the tubing, there to be vaporized. This vapor will flow back to the bulb where it will be condensed and started over on the same cycle. The pressure within the system will correspond to the temperature within the tubing at the point where vaporization takes place, and not with the temperature of the bulb.

50 CASE 8. This case differs from Case 7 in that with the bulb in an erect position, time must be allowed for the liquid in the tubing and gage to vaporize and then to condense in the bulb after which the same conditions obtain as in the first part of Case 7.

51 These cases can be summarized by stating that if vapor-pressure thermometers are properly filled the bulb can be installed in any position and accurate results obtained.

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[6] If the exposed end of the capillary tubing in the bulb is not submerged in the liquid, the capillary tubing and the pressure gage will be filled with liquid by the condensation of vapor, which will necessarily take longer than it would to fill these parts by the displacement of liquid from the bulb through the submerged end of the tubing.

PRECAUTIONS

58 When using a pressure gage recording thermometer the pen arm should be so adjusted that it bears against the paper as lightly as possible and still draws a record, otherwise the friction of the pen on the paper will prevent the pen from moving for small changes in the temperature of the bulb.

59 When changing the chart care should be taken to see that there is no lost motion in the mechanism which revolves the chart. If such lost motion exists, an error in the time will be introduced which is directly dependent upon the amount of lag of the chart.

60 Ink different from that recommended by the manufacturer of the instrument should not be used as the pen may become clogged, or the record line on the paper chart may spread or may not dry within a reasonable time.

61 Before taking readings with an instrument of the vapor-pressure type, time should be allowed for temperature and pressure equilibrium to become established as discussed in Pars. 42 to 51.

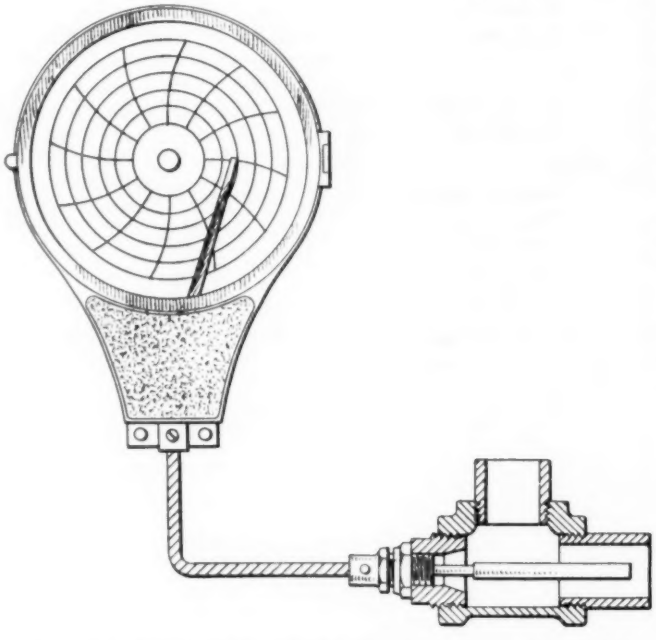

FIG. 13 METHOD OF INSTALLING PRESSURE GAGE THERMOMETER TO MEASURE TEMPERATURES OF FLUIDS IN PIPES

CORRECTIONS

62 There are no corrections other than those established by the calibration that can be applied to the temperature as indicated by pressure gage thermometers.

CALIBRATION

63 The calibration of pressure gage thermometers can be made in several different ways: namely, (*a*) by comparison in thermometer-comparison baths the temperature of which can be controlled with thermometers that have been calibrated by the U. S. Bureau of Standards or other reliable sources;[7] (*b*) by comparison with substances having known melting or boiling temperatures; and (*c*) by comparison with steam of known temperatures, such as the saturation temperatures corresponding to known and attainable pressures.

Scientific and Engineering Symbols and Abbreviations

Proposals for Three Standards Which Have Been Submitted by the Sectional Committee Of the A.E.S.C. to the Sponsors of This Project

IT WILL BE recalled that in the August, 1927, issue of MECHANICAL ENGINEERING, the proposed Standard for Mathematical Symbols was presented to our readers for their information and comment. This was the first proposed Standard to be submitted to the sponsors by the Sectional Committee for the Standardization of Scientific and Engineering Symbols and Abbreviations. Other standards now being prepared by this committee are: Symbols for Heat and Thermodynamics, Photometry and Illumination, Navigational and Topographical, and Abbreviations for Engineering and Scientific Terms.

The Sectional Committee was organized under the procedure of the American Engineering Standards Committee as the culmination of a series of efforts on the part of the A.S.C.E., A.S.T.M., A.I.E.E., A.S.M.E. and other national organizations. The societies which accepted joint sponsorship are the A.A.A.S., A.S.C.E., A.I.E.E., S.P.E.E., and the A.S.M.E. Twenty-nine national societies and associations have appointed official representatives on the Sectional Committee, which is headed by Dr. J. Franklin Meyer of the Bureau of Standards, as Chairman, Dr. Sanford A. Moss, Research Engineer, Thomson Research Laboratory, as Vice-Chairman, and Preston S. Millar of the Electrical Testing Laboratories, as Secretary.

These proposed standards having been approved by a unanimous vote of the Sectional Committee, are now before the five sponsor societies for approval prior to submission to the American Engineering Standards Committee for approval and designation as American Standards, or tentative American Standards. Accordingly, we are reproducing them for the information of our readers, whose comments and criticisms thereon will be welcomed. Communications should be addressed to C. B. LePage, Assistant Secretary, A.S.M.E., 29 West 39th Street, New York, N. Y.

SYMBOLS FOR HYDRAULICS

The proposed tentative American Standard for Symbols for Hydraulics which follows has been developed by a Sub-Committee of the Sectional Committee whose members are Messrs. G. R.

[7] The standard thermometers should be checked for the shifting of their calibrations by checking the ice-point and boiling-point readings by methods described in Pars. . . . and . . . Part 3, Chapter 6. This section of the code does not permit of assuming that the indications over the whole scale have shifted an amount equal to that at the ice point, nor does it permit the use of a standard thermometer, the ice point of which has shifted, without a recalibration by the U. S. Bureau of Standards.

Russell, Chairman, C. M. Fair, Secretary, C. W. Allen, H. K. Barrows, C. A. Bissell, L. L. Daugherty, R. W. Davenport, W. S. Franklin, N. C. Grover, F. L. Hunt, L. F. Moody, and R. S. Weston.

The letter symbols covered in this standard include those employed in the computations for hydraulic power plants, turbines, and pumps.

Acceleration:	
In general	a
Due to gravity	g
Area	A
Channel Flow:	
Area of section	A
Average velocity in section	V
Depth of flow	d
Hydraulic radius	R
Hydraulic slope	S
Length	L
Surface width	B
Kutter's coefficient of roughness	n
Bazin's coefficient of roughness	m
Chézy's coefficient	C
Coefficient:	
Of velocity	c_v
Of contraction	c_c
Of discharge	c_d
Of roughness, Kutter's	n
Of roughness, Bazin's	m
Of Chézy	C
Density	w
Diameter	D
Energy per unit time (power)	P
Friction factor used in expressing pipe loss	f
Head:	
In general	h or H
Elevation head	z
Pressure head	h_p
Velocity head	h_v
Lost head (with appropriate subscript)	h
Hydraulic radius	R
Hydraulic slope	S
Pressure:	
Intensity of	p
Total pressure (force)	F
Pipes:	
Average velocity in section	V
Diameter of	D
Head lost in (with appropriate subscript)	h
Hydraulic radius	R
Hydraulic slope	S
Length	L
Power (energy per unit time)	P
Properties of Water:	
Density	w
Modulus of elasticity	K
Rate of discharge or flow (vol. per unit time)	Q
Slope, hydraulic	S
Time	t
Velocity:	
Absolute	V
Relative to moving casing	v
Of moving casing	u
Viscosity:	
Absolute	μ
Kinematic	ν
(Kinematic viscosity = absolute viscosity ÷ density)	
Weight:	
Per unit volume (density)	w
Per unit time	W
Weirs:	
Head as measured	H or h
Velocity head of approach	h_0
Crest height	Z
Crest length	B
Velocity of approach	v_0

Symbols Relating to Hydraulic Turbines and Pumps

Dimensions:	
Angle between the absolute velocity of the water and the velocity of the runner at any point, measured in degrees	α
Angle between the relative velocity of the water and the velocity of the runner at any point, measured in degrees	β
Axial breadth or depth of runner entrance	B
Diameter of runner or impeller	D
Diameter of runner or impeller vanes at the middle of entrance space	D_1
Diameter of runner or impeller (inside diameter of band or shroud ring)	D_{1b}
Radius to any point from center of runner or impeller	r
Efficiency:	
Hydraulic	h
Mechanical	m
Total or overall	e
Head:	
Total head at any point	H
Potential head at any point	z
Pressure head at any point	h_p
Velocity head at any point	h_v

$$(H = h_v + h_p + z)$$

Power:	
Power, or energy per unit time	p
Power of turbine under 1-foot head	P_1
Power at brake	P_B
Power from water	P_W

NOTE: Where power is to be expressed in horsepower or other units, a statement to that effect should be made.

Speed:	
Revolutions per minute	n
Revolutions per minute under 1-foot head	n_1
Specific speed or type characteristic	n_s

$$n_s = \frac{n\sqrt{P}}{H^{5/4}}$$

P being expressed in horsepower.

Ratio of peripheral speed of runner to $\sqrt{2gH}$	ϕ

$$\phi = \frac{u_1}{\sqrt{2gH}}$$

Velocity:

Angular velocity, in radians per second	ω
Absolute velocity of the water at any point in a rotating runner or impeller	V
Circumferential velocity of a point on a rotating runner or impeller	u
Circumferential or tangential component of the absolute velocity of the water	V_u
Meridional component of the absolute velocity of the water (component in the plane containing the axis of rotation of runner or impeller)	V_m
Radial component of the absolute velocity of the water	V_r
Relative velocity of the water with respect to the moving runner or impeller	v

NOTE: Subscripts 1 and 2 may be used to refer to the points of entrance and discharge in either a runner or impeller, the assumption being that the water always flows from point (1) to point (2). Thus V_1 and V_2 refer to the absolute velocity of the water at entrance and exit from a runner or impeller.

NOTE: The German standard symbols for absolute, relative, and circumferential velocities are c, w, and u. The Greek γ (Gamma) is used for density. The large amount of German literature on the subject of turbines warrants the statement here of these facts.

AERONAUTICAL SYMBOLS

Happily this proposed tentative American Standard for Aeronautical Symbols has been developed at a time when this industry is still young, and consequently will do much toward unifying the literature of this subject. The members of the Sub-Committee developing this proposed standard are Messrs. Joseph S. Ames, Chairman, W. S. Diehl, Secretary, Harvey W. Davis, H. L. Dryden, Donald G. Duke, W. R. Gregg, Alexander Klemin, George W. Lewis, and A. E. Peterson.

Acceleration due to gravity, or gravity constant	g
Air speed	V
Air speed, indicated	V_i
Altitude	h
Angle, dihedral	γ
Angle, effective helix	Φ
Angle of attack	α
Angle of downwash	ϵ
Angle of pitch	θ
Angle of roll or bank	φ
Angle of set of control surfaces (with appropriate subscripts for different surfaces)	δ
Angle of stabilizer setting with reference to lower wing	β
Angle of wing setting (angle between the wing chord and the thrust line)	i_w
Angle of yaw	ψ
Angular velocity	ω
Area, general	S
Area of parts with appropriate subscript	S_p
Area ratio S/b^2	λ
Aspect ratio	b^2/S
(b/c for rectangular wings $= 1/\lambda$)	

Axes of aircraft (left-handed):

Longitudinal	X
Lateral	Y
Normal	Z
Ceiling	H
Center of gravity	c.g.
Center-of-gravity coefficient (with respect to the mean chord)	C_g
Center of pressure	c.p.
Center-of-pressure coefficient	C_p
Chord length	c
Climb, rate of $dh/dt =$	r
Coefficient, absolute	C
Damping coefficient	λ
Density, air	ρ
Density relative to standard air density, i.e., 0.12947 kg-m.$^{-4}$-sec.^{2} at 15 deg. cent. and 760 mm., or 0.002378 lb.-ft.$^{-4}$-sec.^{2}	σ
Displacements:	
Longitudinal	x
Lateral	y
Normal	z
Angular:	
In roll	φ
In pitch	θ
In yaw	ψ
Distance from c.g. to c.p. of horizontal tail surface	f
Drag	D
Drag, absolute coefficient of $D/qS =$	C_D

(This form of coefficient should be used only with absolute units, including $\frac{1}{2}\rho$ in the equation of force. When any other type of unit is used, the form of coefficient should be altered.)

Drag, coefficient of induced	C_{Di}
Drag, coefficient of parasite	C_{Dp}
Drag, coefficient of profile	C_{Do}
Drag, induced	D_i
Drag, parasite	D_p
Drag, profile	D_o
Dynamic (or impact) pressure $\frac{1}{2}\rho V^2 =$	q
Force, cross-wind	C
Force, cross-wind, absolute coefficient $C/qS =$	C_c
Forces (parallel to axes):	
Longitudinal	X
Lateral	Y
Normal	Z
Gap	G
Indraft (inflow velocity)	V'
Kinematic viscosity	ν
Lift	L
Lift, absolute coefficient of $L/qS =$	C_L

(This form of coefficient should be used only with absolute units, including $\frac{1}{2}\rho$ in the equation of force. When any other type is used, the form of coefficient should be altered.)

Lift-drag ratio	L/D
Load factor	n
Loading, specific (with appropriate subscripts for different surfaces)	w
Loading, power; weight per unit power	w_p
Loading, wing; weight per unit area	w_s
Moments:	
Rolling	L
Pitching	M
Yawing	N
Moments, absolute coefficients of:	
Rolling $L/qbS =$	C_L
Pitching $M/qcS =$	C_M
Yawing $N/qbS =$	C_N
Moments of inertia about axes:	
Longitudinal	A
Lateral	B
Normal	C

Pitch ratio, effective	V/ND
Power	P
Power coefficients	$\frac{P}{\rho N^3 D^5} = C_P$; $\frac{P}{\rho V^3 D^2} = C_{P'}$; $\frac{P}{\rho V^5/N^2} = C_{P''}$
Pressure, general	p
Propeller diameter	D
Propeller efficiency	η
Propeller rate of rotation	N
Resultant force	R
Reynolds number (where l is any linear dimension)	$\rho Vl/\mu$
Slipstream velocity	V_s
Span	b
Thrust	T
Thrust coefficients	$\frac{T}{\rho N^2 D^4} = C_T$; $\frac{T}{\rho V^2 D^2} = C_{T'}$; $\frac{T}{\rho V^4/N^2} = C_{T''}$
Torque	Q
Torque coefficients	$\frac{Q}{\rho N^2 D^5} = C_Q$; $\frac{Q}{\rho V^2 D^3} = C_{Q'}$; $\frac{Q}{\rho V^5/N^3} = C_{Q''}$
Velocities:	
Angular:	
Roll	p
Pitch	q
Yaw	r
Linear (component along axis):	
Roll	u
Pitch	v
Yaw	w
Viscosity, coefficient of	μ
Weight	W

LETTER SYMBOLS FOR ELECTRICAL QUANTITIES

The following proposed American Standard for Letter Symbols for Electrical Quantities has been approved by the Sectional Committee on Scientific and Engineering Symbols and Abbreviations and is now before the Sponsor bodies for approval and transmission to the A.E.S.C. It was developed by a Sub-Committee composed of Messrs. J. Franklin Meyer, Chairman, C. H. Sanderson, Secretary, W. H. Burtis, W. J. Canada, E. J. Cheney, W. E. Farnham, C. Q. Fink, L. A. Hazeltine, A. E. Kennelly, R. W. E. Moore, E. K. Post, C. A. Seaone, A. B. Smith, and J. B. Taylor.

Admittance	Y, y
Angular frequency Angular velocity	ω
Capacitance	C
Capacity, electrostatic (see capacitance)	
Conductance	g
Conductivity	γ
Current	I, i
Difference of potential, electric (see note 4)	E, e
Dielectric constant	K or ϵ
Dielectric flux	Ψ
Dielectric flux density	D
Efficiency	η
Electric potential (see note 4)	E, e
Electrical tension (see voltage)	
Electromotive force	E, e
Electrostatic capacity (see capacitance)	
Electrostatic flux (see dielectric flux)	
Electrostatic flux density (see dielectric flux density)	
Energy	W
Flux density, electrostatic (see dielectric flux density)	
Flux density, magnetic (see magnetic flux density)	
Frequency	f
Impedance	Z, z
Inductance	L
Magnetic intensity	H
Magnetic flux	Φ
Magnetic flux density	B
Magnetomotive force	$\mathfrak{F}$
Mutual inductance	M
Number of conductors or turns	N
Permeability	μ
Permeance	$\mathfrak{P}$
Permittance (see capacitance)	
Period	T
Permittivity (see dielectric constant)	
Phase displacement	θ or φ
Power	P, p
Quantity, electric Quantity of electricity	Q, q
Reactance	X, x
Resistance	R, r
Resistivity	ρ
Reluctance	$\mathfrak{R}$
Reluctivity	ν
Self-inductance	L
Susceptance	b
Speed of rotation	n
Voltage	E, e
Work	W

Notes

1 Where distinctions between maximum, instantaneous, effective (root-mean-square), and average values are necessary, E_m, I_m, P_m are recommended for maximum values; e, i, p for instantaneous values, E, I for effective (r.m.s.) values, and P for average value.

2 In accordance with the practice in other branches of engineering, it is recommended that quantities per unit volume, area, length, etc., be represented as far as practicable by lower-case letters corresponding to the capitals which represent the total quantities.

3 In print, vector or complex quantities should be represented by bold-face letters. In typing, overscoring may be used to indicate bold-face letters (vectors).

4 Where a distinction between electromotive force and difference of electric potential is desirable, the symbols E e, and V v, respectively, may be used.

The total value of all air products was $21,161,853 in 1927. Last year, the United States produced 1995 planes valued at $14,504,999. In the first six months of 1928, internal lines of the United States carried under contract 1,278,940 lb. of mail, for which they were paid $2,326,400. The total expenditure by the Post Office on air mail from 1918 to 1928 amounts to $18,924,076.

Engineering and Industrial Standardization

Quarterly Report of Division of Simplified Practice

WITH the completion of seven new simplified-practice recommendations during the second quarter of 1928, industries have now developed a total of ninety-five simplifications in cooperation with the Division of Simplified Practice of the Bureau of Standards, U. S. Department of Commerce.

During the quarter, a total of nine simplified-practice recommendations came before their respective standing committees for review. Three were revised, five were reaffirmed, and one (Simplified Practice Recommendation No. 28—Sheet Steel) the standing committee deemed necessary to divide into two portions, to be published separately, one on sheet steel, and the other on iron and steel roofing—the latter to be known as Simplified Practice Recommendation No. 78. Of the nine recommendations reviewed, six were supported by factual surveys, while estimates of adherence were accepted for two, and one was reaffirmed without either a resurvey or estimate.

Nine general and twenty-one preliminary conferences were held by various industries, under the auspices of the Division of Simplified Practice, for the purpose of discussing proposed simplifications. There were also five general and twelve preliminary conferences held by the Commercial Standards Unit, another part of the Commercial Standards Group. In addition, ninety-seven representative business men visited the Department to gather first-hand information regarding its work. Of this number, five were from foreign countries.

A growing recognition is evident among manufacturers that a fertile source of hidden profits lies in the elimination of excessive variety in the goods offered the public. Lines, items, sizes, types, styles, or models, even brands for which there is little, if any, demand, are being dropped in favor of those that enjoy a better turnover in response to sustained or fairly continuous demand. The resulting concentration of manufacturing and selling effort on stocks thus simplified is yielding tangible benefits, such as smaller inventory investments, better turnover, lower costs, better service, and better profits.

Distributers, wholesale and retail, are finding they can apply simplification to their own stocks, as manufacturers have been doing for some years past, and with similar benefit. This is indicated in the increasing number of instances coming to light of jobbers and merchants who have applied simplification successfully and profitably. As the experience of those who have benefited from this form of waste-elimination effort becomes more generally known, other distributers are evidently taking hold of the idea. That more of them are testing its application in their establishments, or seriously considering doing so, is reflected in the steadily increasing number of inquiries regarding simplification, inventory control, etc., coming into the Department of Commerce. These inquiries cover all kinds of retail business, dry goods, groceries, hardware, auto accessories, plumbing supplies, leather goods, and many more.

Notes of Interest

Speeds of Driven Machinery (Z18.) The American Society of Mechanical Engineers, acting as sponsor for the sectional committee which is to formulate a national standard for speeds of driven machines, has sent out invitations to membership in the sectional committee and an organization meeting will be held as soon as sufficient appointments have been received.

A letter from Germany states that the machine-tool manufacturers of that country now have in mind to standardize systematically the number of revolutions per minute of machine tools on a general basis of geometric or logarithmic progression. It is regarded as beyond question that such standardization will be enormously profitable not only for the manufacturer of machine tools, but also for the use of the latter in production. A tentative proposal is to standardize revolutions per minute from one to five thousand, with a ratio of increase of $1.259 = \sqrt[10]{10}$, or the ten series of the "preferred numbers" system.

In this connection it is interesting to note that the American committee working on machine-tool standards has voted to use the principle of "preferred numbers" in all its dimensional standardization whenever possible.

Progress in Standards for Graphic Presentation (Z15.) A proposed Tentative American Standard on Terminology in Graphic Presentation has been prepared by a sub-committee of the sectional committee on Standards for Graphic Presentation, under the chairmanship of Mortimer B. Lane, of the Census Bureau, Washington, D. C.

Definitions (with discussion) are offered for: Inquiries and Projects, New Orders, Cancellations, Net New Orders, Unfilled Orders, Shipments, Transshipments, Stocks, and Production. A copy of the report is available for reference by those interested.

"Certification" in the Lumber Industry. A pamphlet submitted to the subscribers of the National Lumber Trade Extension Campaign is available, presumably without charge, upon application to the National Lumber Manufacturers' Association, Washington, D. C. This discusses one of the most important industrial "commodity certification" plans that has yet been developed, and will be of interest to all who are concerned with the attitude of trade associations toward the use of specifications and their specific application through designating marks. It provides information as to the terms of the license agreement under which the mark may be used, and the principal effect of such marking upon trade practices and upon consumer acceptance of lumber in relation to competing products.

Economic Gains Through Standardization. The progress of standardization in bringing about better goods for the consumer is evidenced in a recent notice appearing in a number of newspapers reporting the fact that tests by the Bureau of Mines of samples of gasoline from all parts of the country showed very little variation from the average quality. The statement says: "Oil is another great industry that by standardization, consolidation, and cooperation is furnishing the market with a superior and uniform product."

Another newspaper item quotes William C. Durant, discussing the recent Dodge-Chrysler merger, as saying: "Standardization eliminates much waste in the automobile industry, and provides vast improvement on design and mechanical perfection."

In another important article in the New York *Times* of June 10, reporting an investigation of profit trends in American industry, made by the American Association of Cost Accountants, Mr. Bullis, director in charge of research for the association, in the conclusion of his report makes several suggestions looking to the maintenance of net profits at a satisfactory level. His first

recommendation is the elimination of waste by educating the management in business fundamentals, by keeping expenses down generally, *by standardizing products and methods*, by adopting sound credit policies, and by utilizing all by-products in the most profitable manner.

Six New Projects Proposed. The initiation of six new standardization projects for mechanical equipment under the auspices of the American Engineering Standards Committee has been requested by The American Society of Mechanical Engineers. These projects, which are now being considered by the A.E.S.C. are:

(1) Iron and Steel Bars. Standardization of stock sizes, shapes and lengths for iron and steel bars including flats, squares, rounds, and other shapes. The standardization of Woodruff keys, a project now under way under A.E.S.C. auspices, has emphasized the necessity of standardizing the sizes and shapes of iron and steel bars, particularly in reference to the dimensions and tolerances of hot- and cold-finished bars.

(2) Splined Shafts and Splines. Standardization of splined shafts and splines. It is recommended that the scope of this subject include a study of the relations between keys and shafting of various kinds; square and flat keys, both parallel and taper; splines and double keys, etc. Both solid and hollow shafting will be considered.

(3) Electric Sockets and Lamp Bases. Standardization of rolled threads for screw shells of electric sockets and lamp bases. The purpose of this project is the development of thread standards for the new "intermediate"-size lamp socket and base, and the review and revision of present manufacturing practice for the older types.

(4) Stud-Bolt Dimensions. Standardization of dimensions of stud bolts, including thread dimensions and working tolerances.

(5) Gages for Pressure and Vacuum. The standardization of pressure and vacuum gages may include, in addition to specifications for accuracy and temperature of calibration, such items as ratings of capacity; arrangement of graduations, numerals indicator hand, and certain features of the interior mechanism; and the position of stop pins. Establishment of standards for test equipment and standard methods for testing gages have also been recommended.

Besides decreasing the accident hazard, it is expected that the work will benefit manufacturers and purchasers of gages by replacing the great number of sizes and types now being manufactured by a comparatively small number of standard sizes and types based upon the findings of the committee of technical experts.

(6) Leather Belting. If approved, this project will cover, as requested by the A.S.M.E.: 1, Quality (standard material specification); 2, Capacity (horsepower rating); 3, Weight (dimensions, thickness, and weight), and 4, Care and Maintenance of Belting.

Precedent for belting standardization is found in the work of the American Petroleum Institute, which has established standards for all types of belting used in the oil industry. The Institute estimates that its specifications and recommendations for care and usage increase the service value of belting purchases by 25 per cent.

It is believed that such standardization, and the broader use of the test data underlying it, would lead to a great increase in the present knowledge of the properties of leather belting.

Standards for Letter Symbols (Z10). Three sub-committees of the sectional committee on Scientific and Engineering Abbreviations and Symbols have recently completed their work to the point of submitting proposed standards to the sponsors of the following proposed tentative American Standards: "Symbols for Hydraulics," "Aeronautical Symbols," and "Letter Symbols for Electrical Quantities."

These standards have already been circulated for criticism and comment, the results of which have been incorporated in the present text. The chairmen of the sub-committees which developed these reports are: "Symbols for Hydraulics," George E. Russell, Professor of Theoretical Hydraulics, Massachusetts Institute of Technology; "Aeronatical Symbols," Joseph S. Ames, Director of the Physics Laboratory, The Johns Hopkins University; and "Letter Symbols for Electrical Quantities," Dr. J. Franklin Meyer of the Bureau of Standards.

These three proposed standards are reproduced on pages 797 to 800 of this issue of MECHANICAL ENGINEERING.

Scheme for Identification of Piping Systems (A13). The National Safety Council and The American Society of Mechanical Engineers, acting as joint sponsors, submitted a proposed Scheme for Identification of Piping Systems on July 9, 1928, to the A.E.S.C. for approval and designation as a Recommended American Practice. As soon as this report receives the approval of the A.E.S.C. it will be issued by the A.S.M.E. in pamphlet form.

Skid Platforms (S.P.R. 95-28). In accordance with the unanimous action of a general conference of representative manufacturers and users of skid platforms held in Washington on June 28, 1928, the Department of Commerce submits for the approval of the industry the following list of clearance dimensions for skid platforms;

a Clear height from bottom of runners or other supports to under side of platform, 8 in. and 12 in.

b Minimum horizontal distance between inside of runners or other supports, 29 in.

If approved by manufacturers and users of skid platforms, this recommendation shall become effective October 1, 1928.

Safety Rule for Construction Industries. On June 29, 1928, a conference on this subject met in the Council Room of the A.S.M.E., having been called by the A.E.S.C. at the request of the Association of Governmental Labor Officials of the U. S. and Canada.

The Conference was well attended by official representatives of 23 societies, trade associations, and governmental organizations interested in this problem. After full discussion it was voted "that a set of national safety regulations for construction work be developed by a sectional committee under the auspices and procedure of the American Engineering Standards Committee." A steering committee was then appointed to block out the scope of work on safety measures for the construction industries, and to advise in regard to the organization of the work, including such matters as the constitution of the sectional committee, sponsorship, etc.

This committee met in the afternoon and made the following recommendations:

a That the Associated General Contractors of America, and the Association of Governmental Labor Officials of the United States and Canada be recommended to the A.E.S.C. as joint sponsors for the proposed safety rules for the construction industries.

b That it be recommended to the A.E.S.C. that the scope of the proposed code or codes on construction work be confined to the construction, demolition and repair of buildings; including excavation, foundation work, steel erection, scaffolding, lighting, openings, temporary floors and stairs, in relation to accident hazards to employees and to the public.

New Year Book of A.E.S.C. Available. The 1928 edition of the A.E.S.C. Year Book is just off the press, and a copy together with an up-to-date list of approved standards may be had for the asking.

For a review of the Committee's activities attention is called to the sections dealing with "The Year's Work," and the classified list of Standardization Projects (pages 28–53).

The Conference Table

THIS Department is intended to afford individual members of the Society an opportunity to exchange experience and information with other members. It is to be understood, however, that questions which should properly be referred to a consulting engineer will not be handled in this department.

Inquiries will be welcomed at Society headquarters, where they will be referred to representatives of the various Professional Divisions of the Society for consideration. Replies are solicited from all members having experience with the questions indicated. Replies should be as brief as possible. Among those who have consented to assist in this work are the following:

ARCHIBALD BLACK,
Aeronautic Division

A. L. KIMBALL, JR.,
Applied Mechanics Division

H. W. BROOKS,
Fuels Division

R. L. DAUGHERTY,
Hydraulic Division

WM. W. MACON,
Iron and Steel Division

JAMES A. HALL,
Machine-Shop Practice Division

CHARLES W. BEESE,
Management Division

G. E. HAGEMANN,
Materials Handling Division

J. L. WALSH,
National Defense Division

L. H. MORRISON,
Oil and Gas Power Division

W. R. ECKERT,
Petroleum Division

F. M. GIBSON and W. M. KEENAN,
Power Division

WINFIELD S. HUSON,
Printing Industries Division

MARION B. RICHARDSON,
Railroad Division

JAMES W. COX, JR.,
Textile Division

WM. BRAID WHITE,
Wood Industries Division

Wood Industries

Manufacture of Wood Flour[1]

WI-1 What methods are employed in the manufacture of wood flour and for what purposes are the products used?

Valuable information on this subject appears in the report of the National Committee on Wood Utilization, entitled "Saw Dust and Wood Flour," issued by the U. S. Department of Commerce. The following information taken from the bulletin may prove valuable.

The estimated annual production of wood flour in the United States is slightly in excess of 24,000 tons, with a total value of about $750,000. In addition to the domestic supply, 6413 tons were imported from Europe in 1926. Fully 75 per cent of the wood flour manufactured in the United States is made from white pine and the success of the enterprise depends upon having a combination of, first, sufficient raw material of the proper kind, and second, an abundant supply of cheap electric power for reducing the raw material to flour.

Wood flour might properly be considered as a by-product of the lumber industry because over 60 per cent of that produced is manufactured from wood shavings and sawdust. However, the sawmill or planing-mill owner should not be misled by the impression that all of his sawdust, chips, and mill ends can be led through any type of grinder and be made to yield handsome profits. It is not only necessary for the successful producer of wood flour to study the most approved and efficient grinding methods, but he must also study carefully the requirements of the consumer.

[1] This subject has been discussed in a previous issue.

About 40 per cent of the wood flour produced in this country, and apparently all of that made in Northern Europe is ground in stone mills, which are an adaptation of the old burrstone mills, used for the grinding of wheat and other grains. There are a number of patented pulverizing machines on the market which in general might be divided into three types: attrition mills, (double or single) hammer mills, and roller mills.

In the manufacture of wood flour, there is a constant danger of dust explosions and fires, which are started inside the grinding mills, usually by small pieces of steel that go through the mill with the shavings and other material being ground. This hazard may be reduced and at the same time damage to the mill reduced by providing an electric magnet to pick out the metallic objects.

It is estimated that 15,500 tons of wood flour enters into the manufacture of linoleum. In the manufacture of explosives, wood flour has its greatest usefulness as a constituent of dynamite and is used to the extent of about 7500 tons annually. Kieselguhr, a fine siliceous earth, was the original absorbing medium used in the manufacture of dynamite, but this is given almost entirely to the use of active constituents of which wood flour in varying degrees of fineness, supplemented in some cases with wheat flour, corn meal, and sawdust, enters as the most important materials. Miners, quarrymen, and other users have learned to associate light color with fresh, high-quality dynamite, and for this reason the wood flour entering into the manufacture thereof must be light in color. The situation is unfortunate because many species of slightly colored woods could be made into equally good wood flour.

With the successful development of phenol resins, there has been a sizable increase in the quantity of wood flour used as a filler with these resins when molded into usable articles such as radio dials, telephone parts, etc. The product for this purpose must be of a fine grade; one manufacturer reports that it must pass through a 60-mesh sieve, but it is thought that most other manufacturers demand even finer grades. Doll manufacturers also make use of wood flour in the manufacture of unbreakable dolls. Manufacturers of oatmeal wallpaper also demand this product. Another use is in the manufacture of composition flooring made chiefly from caustic-magnesia cement, sawdust, and wood flour.

The chief problem confronting industry according to the report of the Committee is for further uses of wood flour, and it is the hope of the Committee that it may hear from any individual or organization familiar with additional actual or possible applications for this interesting by-product of the tree. Readers of MECHANICAL ENGINEERING will render a service if additional discussion of the subject is offered in this department. (P. H. Bilhuber, Assistant Factory Manager, Steinway & Sons, Long Island City, N. Y.)

Question to Which Answers Are Solicited

Boiler Corrosion

P-1 On boilers without economizers fed through feedwater heaters operating at 210 deg. fahr., or thereabouts, has there ever been evidence of corrosion due to lack of deaeration? If so, under what conditions and circumstances did it occur?

Correspondence

CONTRIBUTIONS to the Correspondence Department of Mechanical Engineering are solicited. Contributions particularly welcomed are discussions of papers published in this journal, brief articles of current interest to mechanical engineers, or comments from members of The American Society of Mechanical Engineers on its activities or policies in Research and Standardization.

Better Riveted Joints

To the Editor:

I was much interested in the editorial on riveted joints in the July issue of Mechanical Engineering, as it brought to mind the suggestion made about six years ago to our research committee that we at least get together the bibliography of riveted joints. I believe that was done. I feel that the reason that our rules have not been changed for a decade is because these rules are safe and rational. Joints made from designs following these rules have been safe and satisfactory joints: joints which could be inspected, joints which are dependable. I do feel, however, that there are many things which we should still know. Stress distribution and concentration, eccentric loading, axial tension and its effects, are a few of the things which the practitioner should know as well as the research specialist.

Arthur M. Greene, Jr.[1]

Princeton, N. J.

Supercharging Diesel Engines

To the Editor:

I wish to call attention to the thermodynamics on page 475 of the June, 1928, issue of Mechanical Engineering. The next to last paragraph, first column, in the article on "Supercharging Diesel Engines" is interesting, if true.

The author states, "This air on reexpansion to atmospheric pressure through the nozzle C will have its temperature reduced to $(540 \times 14.7)/16.2 = 490$ deg. abs., the temperature after reexpansion becoming 30 deg. fahr., and the pressure being atmospheric but containing the same weight of air per cubic foot as was contained per cubic foot when its temperature was 80 deg. fahr. and its pressure $1^1/_2$ lb. gage." The author has forgotten his elementary thermodynamics.

I have made the following calculations to show that the assumption is over 7 per cent in error, using the given pressures and the initial temperature:

From the fundamental gas equation $PV = MBT$, letting $V = 1$ cu. ft., the initial density $M = (16.2 \times 144)/53.34 \times 540 = 0.0810$ lb. per cu. ft. Also from the relation between absolute temperatures and pressures

$$T_2/T_1 = (P_2/P_1)^{\frac{n-1}{n}}$$

where $n = 1.4$,

$$T_2 = 540(14.7/16.2)^{0.2857} = 526 \text{ deg. abs.}$$

With this final temperature, 66 deg. fahr., the resulting density is found to be

$$M = \frac{14.7 \times 144}{53.34 \times 526} = 0.0755 \text{ lb. per cu. ft.}$$

The percentage difference of the initial density compared to that of the final density is then found to be about 7.3 per cent.

The author's fallacy lies in the expression equating the absolute temperatures proportional to the pressures which is only true for a constant volume change of state as expressed in the law of Charles.

Philadelphia, Pa. L. Morgan Porter.[2]

Higher Steam Pressures

To the Editor:

Referring to the paper entitled "Higher Steam Pressures" (Trans. A.S.M.E., vol. 50, no. 15, May-August, 1928, p. 28), by Nevin E. Funk, the form of load curve called "occurrence" curve by the author is not, as he states, "new," for the writer developed it in 1914 (see Trans. A.I.E.E., vol. 33, part 1). The curve has more useful characteristics than Mr. Funk points out, which may be briefly outlined as follows:

From the usual load curve expressed as a per cent power curve, i.e., with maximum power as 100, as shown in Fig. 1 herewith,

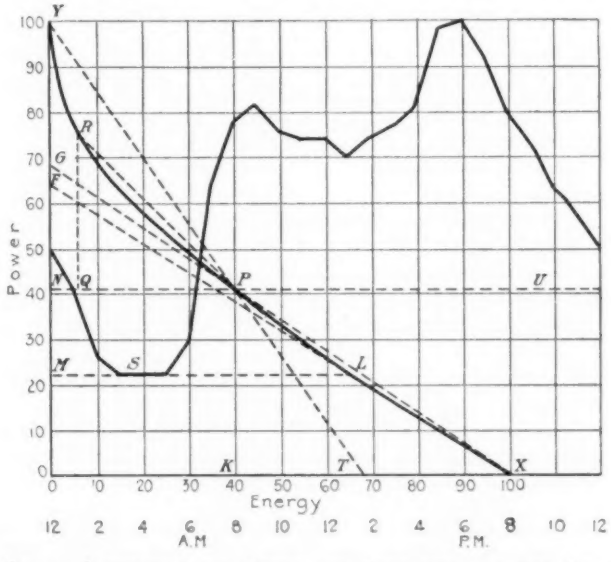

Fig. 1 Ordinary Load Curve and Corresponding Per Cent Load Curve

there is derived a curve which the writer has called the "per cent load" curve. This is shown at $YRPLX$ of the figure. The ordinates of this curve show relative power, with maximum power as 100, and abscissas show "peak energy" expressed in terms of the total energy represented by the load curve as 100. Referring to the figure, the abscissa OK of the point P gives the percentage of the total energy that is included above the power line $NQPU$. The coordinates are then "peak energy" and "base power." "Base energy" and "base power" might have been used, but the choice made simplifies the use of the curve. "Base energy" is given by the abscissa measured to the left from X; that is, "base power" is KP and "base energy," KX; "peak power," NY, and "peak energy," NP.

This curve is made up of a straight line from X up to the point L of minimum power MSL, and a curve tangent to this straight line XL at the point L. This part XL is straight, because energy and power are directly proportional up to the point of minimum power.

This "per cent load" curve possesses several interesting properties:

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1 The line XL continued, intercepts the Y-axis at a point F; OF is the load factor of the total load.

2 A line drawn from Y through any point P intersects the X-axis at point T; the load factor of the peak load above P is equal to the load factor OF of the total load multiplied by OT; $OF \times OT$ is the load factor of the peak load above P.

3 A line drawn from X through any point P intersects the Y-axis at the point G; the load factor of the base load below P is OF/OG.

4 The load factor of any intermediate load, e.g., between P and R, is equal to $OF \times \tan QRP$.

These theorems are proved in the paper cited.

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New York, N. Y.

Some Common Delusions Concerning Depreciation

TO THE EDITOR:

In the discussion of his paper on "Some Common Delusions Concerning Depreciation" in the August issue of MECHANICAL ENGINEERING, page 617, Mr. Ernest DuBrul deals with the question of depreciation reserves and voices very strongly his opinion that depreciation should be computed not on the basis, as has so often been adopted by accountants, of taking the original cost of the assets and dividing it by the estimated life, but should be computed on the replacement value of assets.

The basis of replacement value of assets for the purpose of computing depreciation is entirely fallacious and is unsound in principle. This statement is capable of proof in many ways. Depreciation is a charge made from period to period for the loss occasioned by wear and tear of the capital assets of the business. Depreciation is charged in the accounts of a business either monthly or annually or at any other periodical division of time as desired, but in the final analysis it is nothing more or less than an attempt to charge the cost of capital assets to the periodical operating accounts of the business instead of having the charge come in one period, either when the assets are bought or when they wear out. Monthly or annual charges for depreciation have the effect of equalizing the capital costs of operating a business over the life of the assets with which the business is carried on.

In a very general way, businesses may be said to run in cycles or periods of time which to some extent coincide with a generation of people. A generation may be assumed to be a period of approximately thirty years, on the assumption that a man's useful business career is between the ages of 30 and 60. It is therefore contended that each generation should pay for itself. That is to say, the cost of living which occurs during the period of a generation should be absorbed by the people of that generation, and not be passed on to the next generation, and likewise the people of one generation should not be asked to pay for any excessive cost of living which might arise in the next generation. Applying this principle, we arrive at the conclusion that each generation should pay for the cost of the capital assets of productive enterprises during the life of that generation.

A simple example of this would be a public utility furnishing, let us say, electric current to the people of a community. Let us assume that the utility was purchased in the year 1900 and machinery was set up at that time to provide a certain community with electricity. The funds to purchase the capital assets of the enterprise were partly paid for by public subscriptions among the people of the community, while further funds were obtained through borrowing on an issue of first mortgage sinking-fund bonds. It is one of the elementary principles of investment that an investor should receive a fair rate of return on his capital, plus the return of his capital eventually. Now the question is: What should be the charge for electric current?

In the first few years of the enterprise no one would be able to guess, with any degree of accuracy, what would be the replacement cost of the assets. Therefore it would be exceedingly difficult to make any depreciation charge for the purpose of fixing selling prices of current other than one based on the original cost of the assets. In years to come it might be discovered that owing to conditions that had arisen subsequent to the War, there was a material increase in the cost of replacement and that in a general way the costs of commodities had ascended to a high level to which it appeared they were likely to continue. Under such circumstances it would become necessary to step up the cost of current to take care of the added replacement cost which had just been ascertained. If such increased cost were ascertained, let us say, about five years or so before the capital assets were theoretically due for replacement, it would mean quite an increase in cost and selling prices, all of which would not be practical.

We therefore get back to the theory that, assuming the electric-light plant was good for 30 years, the first generation of people from 1900 to 1930 should pay for its cost in the cost of current. The next generation of people from 1930 to 1960 should pay for the second replacement at the original cost plus the higher cost due to the increased cost of commodities. There is no reason why the first generation shouldpay for the added cost of a plant which is for the benefit of a second generation.

Costs are constantly increasing from cycle to cycle, and probably have done so ever since the world began, and it is therefore contended that the theory of each generation's taking care of its own cost is thoroughly sound in practice.

Therefore, in conclusion, the writer contends that depreciation should be computed either by the rough and ready original-cost method divided by the approximate number of years' life of the plant, or by the more refined method known as the annuity basis, which, however, has its basis on original cost. However, where extraordinary circumstances arise, such as did arise temporarily during the Great War, where commodity prices soared to extraordinary heights and profits were made in proportion, there is no doubt that allowances should have been made for the writedown of any plants built during such a period. This is amply illustrated by the special allowance made by the Government at that time known as "amortization."

With regard to the recommendation that depreciation reserves be kept in liquid securities as a real cash reserve so that they will be promptly available when needed, the advisability of doing this is seriously questioned. While in some cases such as mines and other wasting assets it may be highly desirable, it occurs to the writer that in the case of ordinary manufacturing plants and trading operations which have a more or less permanent existence, a concern can very well afford to reinvest its depreciation reserves either in added capacity or in increased inventory. Generally speaking, under normal circumstances more profits should be made out of funds invested in the business than invested in outside securities, and it is always possible to estimate in advance the time for replacement of capital assets and have the money available when the time occurs for such replacement. This may necessitate the investment of additional capital, which, however, should not be so difficult if the business is successfully operated.

The recommendation made by Mr. DuBrul that depreciation money should be kept in securities seems to the writer only of value in cases of concerns operating with wasting assets or concerns whose managements are not able to properly watch their finances.

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MECHANICAL ENGINEERING

A Monthly Journal Containing a Review of Progress and Attainments in Mechanical Engineering and Related Fields, The Engineering Index (of current engineering literature), together with a Summary of the Activities, Papers and Proceedings of

The American Society of Mechanical Engineers

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Let the War Go On!

AS WARS are won by the nations with the greatest productive capacities, so business competition hinges on maximum production at minimum cost. The smashing battles for orders that are being waged today in automobiles, radio, household machinery of all kinds, and many other lines have brought about a situation that was paralleled only during the war. The brains of those who know how to improve production methods and the plants of those who build tools are again under the stress of a great war—this time, however, for markets and dollars.

There is the same impatience at delayed deliveries, and the same intense urge for quantity. Rapid shifting from an improvement to a later one, constant search for better ways, mark this conflict. Fortunately it is bringing our needs and our luxuries to us at a lower cost, and the new methods developed in this stern competition are available for other production operations. Let the good war go on!

Impartial Expert Evidence

THE practice of calling expert witnesses in court cases has raised many questions in the minds of the members of those professions from whose ranks such witnesses are drawn, and it seems impossible for the public to understand how professional men can honestly have different opinions regarding the same groups of facts. A committee of the New York State Bar Association has prepared a bill for submission to the Legislature which has as its object the correction of abuses in giving expert evidence where the bias and prejudice of experts in favor of their employer is plainly manifested. The bill would permit any court to appoint of its own volition or on motion of one of the parties from one to three impartial experts to examine the issue and testify at the trial. These experts are to be subject to the same examinations for competency, bias, and qualifications, and the jury is to be instructed that their evidence shall be weighed along with that of experts produced by the parties to the issue. These experts are to be examined by the court and may be cross-examined by both parties. Compensation is to be apportioned on the outcome of the case. One novel proviso requires experts to furnish a written statement of conclusions reached to the court and to both the parties.

The bill has been read by several engineers and it seems to have sufficient merit to be worthy of trial. Whether it will bring about an agreement among the experts as to the essential facts in any case is problematical. Experts of integrity may often hold divergent opinions in the application of the same facts. The important thing is to have them all available to the experts who are called upon for an opinion. Some cases have shown that it is possible for engineers on opposite sides to agree on facts. This is an approach toward experts serving both sides as well as the cause of justice, and saves time and expense. If the court's witnesses can aid in bringing about an agreement on the facts involved, a substantial step forward will result.

Remodeling Agriculture

IN A GREAT many respects, American agriculture is still in the cottage stage of development. Just as a century ago shoes and woolens were made by individual craftsmen, so today a large part of our farm produce is grown on a small scale. And while the modern farmer cannot get along without machinery and while this machinery is improving rapidly, and new devices are being made and their use being extended, great concentrations of agricultural producing power are not common. A description of one of these, however, appears in this issue of MECHANICAL ENGINEERING along with other interesting discussions of the engineering and economic problems of agriculture which occupied the honor place on the program of the A.S.M.E. Summer Meeting.

These papers show that the agricultural problem has a definite engineering phase. Mr. Campbell's experience, which is reported in detail, indicates that the application of machinery on a large scale is successful in producing wheat and flax at low cost. Other developments of the engineering mind may reduce the costs still further. It is logical to believe that the principles Mr. Campbell used so successfully can be applied to other farm products. As engineering skill has made over industry generally, so it can remodel agriculture, transforming it from a method of making a living to a sound industry that will attract the best brains and capital.

The Powdered-Coal Diesel Engine

THE original idea of Rudolph Diesel was that of an engine which would burn powdered coal in accordance with the cycle which bears his name. At the time this did not prove successful, and very shortly afterward the idea was abandoned. The German companies which took over the Diesel patents proceeded to develop an oil-burning engine and did it in a remarkably successful manner.

A few years ago, however, the idea was taken up again in Germany by several investigators. Of these Pavlikowski was apparently the only one to achieve actual success. He found that a Diesel-type engine can actually run on powdered coal broken up to a fineness not exceeding that used in boiler firing, and that to all practical purposes any kind of coal can be used more or less successfully. As usual, many of the troubles anticipated in advance never occurred, and, for example, the wear on the cylinder and piston rings in the powdered-coal engine proved to be quite reasonable, and certainly not sufficient to place any

obstacles in the way of commercial utilization of the engine.

It need hardly be said that a Diesel engine running on powdered coal even with a lower efficiency than on oil would prove to be of immense importance commercially. One thing that retards the adoption of Diesel engines for energy generation is the question of the cost of oil. Just now we in the United States are passing through an era of low oil prices. Coincidentally, however, we are using up like spendthrifts the patrimony of ages, and burning up in a comparatively few years resources which under proper management should last the country for generations to come.

There is, therefore, a certain reluctance with regard to adopting a form of power generation, the economy of which is dependent on the price of oil. When it comes to coal, however, there can be no such reluctance. Our coal resources are so enormous that even if utilized at a rate several times greater than that of today they would still last for many scores, possibly hundreds, of years. The situation in the coal industry, moreover, is such that high prices need not be feared. In fact, the increasing mechanization of coal mines would lead one to believe that lower prices will come, combined with a higher standard of living of those employed in that industry. If powdered coal can be actually used in commercial Diesel engines this will be a great boon to the manufacturer of such engines, who then will find a far greater market than that of today; to the coal industry, which at present is suffering from underproduction not only in this country but in England as well; and finally and mostly to the public, which will obtain a new and convenient form of power generation and will not have to waste comparatively rare oil, but will rely instead on our plentiful abundance of coal.

Super-Conventional Design

IT IS typical of human nature to look for improvements in distant fields. That the next pasture is always greener has been the saying for thousands of years. The small-town fellow tries to get away to the large city to look for opportunities, while the big-city chain store comes to the small town and manages to find there its opportunity.

The same apparently applies to machinery. It is probably much easier—certainly more fun—to improve existing machinery by making radical changes than by refining present designs. In this country, particularly, where records are valued for their own sake, there is an unquestioned desire to have the plant with the biggest steam turbine, the highest steam pressure, and the topmost steam temperature. This applies also to marine engineering. When the Diesel engine began seriously to threaten steam on the high seas, the first thought was to break away entirely from approved practice and introduce pressures and temperatures which up to that time had been unheard of in marine plants. Thus Sir Charles A. Parsons proposed his famous turbine, operating at 500 lb. and 700 deg. fahr.; and this tendency was actually embodied with considerable success in the *King George V*.

But then the "Beaver" class ships of the Canadian Pacific Fleet—very up-to-date and master-like in their design—beat the efficiency records of the *King George V* under practically conventional steam conditions of 250 lb. per sq. in. and 650 deg. fahr.

A still more remarkable example of the possibility of obtaining high efficiency by means of intensive study of plant equipment rather than by radical departures from standard design is shown by the Padiham Central Station, described in an abstract in the "Survey of Engineering Progress" in this issue. This station could have been built fifteen years ago exactly as it is today. Scarcely an invention made in the last fifteen years has been incorporated into the design of this station, aside from some measuring or indicating devices, and yet it gives the surprising efficiency of nearly 21 per cent at an initial cost of about $60 per kilowatt completely installed.

To make the story complete, it may be asked why the Padiham Station or one like it was not built fifteen years ago. The answer is probably found in the practice of the chain stores which were referred to at the beginning of this editorial. When the big-town chain-store system installs a store in a small town, a boy raised in a small town is placed in charge of it. It takes years of life in a large city to make a boy born in the country realize the opportunities of his home town, and it was only as a result of the thorough study of the engineering features involved in the most modernly equipped plants that the design of the super-conventional Padiham plant became possible. There is no question that just as in military tactics it becomes necessary to consolidate a position after each advance, so in engineering it pays to stop from time to time and look backward to make sure that in the hurry of the forward rush, important opportunities have not been overlooked.

Carbon vs. Alloy Steels

UP TO, SAY, twenty-five years ago, carbon steels were practically the only ones used. Hadfield's manganese steel was the first to reveal what alloying can do to steel, but it had a narrow range of uses and did not come into real competition with carbon steels. Taylor and White's high-speed steel was spectacular, but again very clearly limited to one specific field. As a general material of construction in bridges, structural work, and machinery, carbon steel was preeminent. However, alloy steels have gradually forged to the front. The early nickel and chrome-nickel steels had properties decidedly superior to those of carbon steels of the day, with the important limitation, however, that these properties would be imparted to the alloy steels only when the latter were properly made and properly heat treated. This was not always the case, and there was therefore a certain amount of distrust, more or less indiscriminate, of heat-treated material and alloyed material. It was fortunate for the alloy steels that their appearance on the market coincided roughly with that of the automobile. The automobile decidedly could not be built well of such carbon steels as were then available, for it required a combination of comparatively light weight, high resistance to shock and vibration, and considerable tensile strength and ability to resist deformation in at least some of its members. Willy-nilly automobile manufacturers had therefore to devote a part of their attention to obtaining such steels as would satisfy these requirements, and this gave a tremendous impetus to the development and manufacture of alloy steels. At about the same time the properties of vanadium as an inhibitant of brittleness induced by vibration were recognized, which constituted an added argument in favor of the use of alloy steels. The combination of all of these factors gradually caused the pendulum of opinion among engineers to swing the other way, and created an impression that when a strong part was to be made it must be produced out of nickel, chrome-nickel, or chrome-nickel-vanadium steel. In addition to this alloy steels were expensive, and there is unquestionably a feeling in the back of the mind of the average consumer that what is expensive ought to be good. Alloy steels therefore began to be used somewhat indiscriminately in places where the necessity for them was more apparent than real. It is significant in this connection that another great transportation industry, namely, the railroads, has never become really excited over the use of alloy steels. Carbon-vanadium steel was extensively adopted by them for axles, but all outside efforts to make the railroads introduce alloy steels elsewhere have more or less failed.

A more rational feeling in this connection is beginning to appear among engineers today. Substantially, the ultimate physical properties of carbon steels depend on the rate of cooling from the austenitic stage, i.e., from above the upper critical point Ar. If this cooling is extremely rapid the martensitic or troostitic stage is trapped and the metal becomes extremely hard. By cooling at a slower rate the sorbitic stage is trapped, which gives the metal medium hardness and great toughness. Finally, by slow cooling the pearlitic stage is reached, and the metal is soft and highly ductile. It is not always easy or possible to trap the exact stage required, particularly in heavy pieces where it is next to impossible to achieve a uniform rate of cooling. The result is that unless the process of cooling is entirely controlled there may be a hardening of the outside layer and gradual softening as we go inward, with possibly a soft heart. The addition of nickel, for example, produces structural changes in the steel which permit obtaining a fairly uniform hardness throughout the piece.

It is obvious, however, that the area of cross-section and shape of the piece are in many cases such as to permit a controllable cooling with modern, already highly developed methods and equipment, and where such a controllable cooling is possible, carbon steel can be made substantially good enough to satisfy the requirements in a great many cases where alloy steel is used today, and with the additional advantage of a very much lower cost. The recognition of this fact has been already apparent in the automobile industry, where a high degree of metallurgical knowledge is apparently common and a close tab is kept on costs of production. In other branches of mechanical engineering it might also be well to consider that under proper conditions very excellent results can be obtained with plain carbon steel, and, for example, in the case of rails—barring those instances where manganese steel is used when the question of wear is particularly important—plain carbon steel has proved to be not only cheaper but actually more reliable than special alloy steels.

The only exception to the foregoing may be made in favor of silicon steel, partly because its cost is fairly reasonable as compared with other alloy steels, and also because silicon seems to impart to carbon steel certain properties which cannot be attained by heat treatment today, in particular, the raising of the elastic limit.

James Edgar Denton

DR. JAMES EDGAR DENTON, Professor Emeritus of Engineering Practice, Stevens Institute of Technology, died at the age of 73 years on July 22, 1928, after a lingering illness. He had been bedridden for about fifteen years, first only partially, and finally to a point where paralysis made it impossible for him to move without assistance.

Dr. Henry Morton, when president of the Stevens Institute of Technology, believed that some of the professors should keep in active touch with the outside world. He encouraged Dr. Denton to conduct a number of researches and also to do commercial work in addition to his teaching. Dr. Morton established what was called the Department of Tests, and much of Dr. Denton's work was done under this department. This and other work served as the basis of a number of reports, and of scientific papers, presented to engineering societies. He made tests on early forms of steam turbines, and was among the first to appreciate the possibilities and to predict the supremacy of the steam turbine. His early work in the field of refrigeration and the careful tests he made of refrigerating plants would in themselves, serve to perpetuate his name, as would also his work on lubrication and lubricants. He was associated in the development of the automobile at such an early day that those backing the enterprise did not appreciate the value of many new features which were developed and which are now embodied in standard constructions. He and his classmate and lifelong friend, Prof. Samuel D. Graydon, formed a copartnership and operated a machine shop under the name of the Graydon & Denton Manufacturing Co. for the manufacture of special machinery. He constructed a section of the New York Aqueduct, where he put in many strenuous hours in tunneling through rock that was difficult to blast and where many adverse conditions were met and overcome. He designed a rock drill especially suitable for the work that made a record for the most rapid rate of progress. He cooperated with Prof. Wm. A. Rogers and with Mr. Geo. M. Bond in establishing standards of length for this country.

James Edgar Denton was born of New England parents, in 1855, at Piermont, New York, where his father was employed as a master blacksmith of the Erie Railroad.

In 1858 the family moved to Cambridgeport, Mass., and subsequently settled in Brighton, Mass., in whose public schools the son received his education up to about twelve years of age. He was then withdrawn from school for a time, and worked for a year in a sewing-machine repair shop in Boston until the family removed to Jersey City to enable the father to return to the service of the Erie Railroad Company, to take charge of one of their shops.

After a couple of years spent in a Jersey City public school, young Denton attended the Bryant & Stratton Business College in New York; in 1871 he entered Stevens Institute as a member of its first regular class, and was graduated in 1875.

After graduation he entered the personal service of Professor Thurston, then occupying the Chair of Mechanical Engineering at the Institute, to take charge of the testing work carried on by Professor Thurston as a separate department known as the Mechanical Laboratory. To this work he added, in 1878, the instruction in mathematics at the High School.

In 1879, during about a year's illness of Professor Thurston, he took temporary charge of the Engineering Department, and organized a systematic course of shop practice.

In 1880 Mr. Denton laid before Dr. Morton a plan for supplementing the theoretical instruction in engineering by a series of experimental exercises designed to give the student an opportunity of testing for himself the truth of the principles and formulas which the textbooks represent as governing the design and operation of practical machinery. This led to the organization of the course of experimental exercises given to the senior students in the summer or preliminary term of the Institute, which was commenced with the class of 1881 in the summer of 1880, and was the first systematic effort to provide a course of instruction of this kind, aiming to cover examples of all the principal applications of the theoretical matter covered in mechanical engineering courses.

In the management of this department Prof. D. S. Jacobus became associated with him, and they developed its resources together until 1898, when Professor Denton succeeded Professor Wood in the Chair of Mechanical Engineering. He received the honorary degree of Doctor of Engineering from Stevens in 1906.

Dr. Denton was life member of The American Society of Mechanical Engineers, which he joined in 1881, and a member of the American Society of Civil Engineers, American Institute of Mining Engineers, American Institute of Electrical Engineers, American Association for the Advancement of Science, Society for the Promotion of Engineering Education, Society of Naval Architects and Marine Engineers, New England Water Works Association, Engineers' Club of New York, and Delta Tau Delta fraternity, as well as of the Baltusrol, Morris County, and Madison golf clubs. He was also a member of the World's Fair Commission on the Jury of Awards in Engineering at Chicago in 1893, and at St. Louis in 1904.

A.S.M.E. Summer Meeting in Minnesota

Well-Planned and Well-Executed Program of Excursions, Sightseeing Trips, and Good Papers, Thoroughly Discussed; T. D. Campbell and R. G. Budd Speakers at Dinner

ST. PAUL and Minneapolis cooperated with splendid results in the successful Summer Meeting of the A.S.M.E. held August 27 to 30, 1928, in these progressive cities. A well-planned and happily carried-out program of excursions, sightseeing trips, and good papers, thoroughly discussed, made this a memorable occasion. Over 300 registered, 94 members and guests coming by boat through the Great Lakes from Buffalo, stopping at Duluth for a view of the Iron Range, and visiting Winnipeg as the guests of the Engineering Institute of Canada with the Minnesota Federation of Engineers and Architects.

Thomas D. Campbell, of Hardin, Montana, and Ralph G. Budd, of St. Paul, were the feature speakers at the dinner on Wednesday evening, which was presided over by Conrad N. Lauer, of Philadelphia, member of the council. Both of these speakers are engineers who have made outstanding contributions to the great industries of the Northwest. Mr. Campbell, a mechanical engineer, has turned farming into an industry. His address on some of the American agricultural problems is the leading article in this issue and is followed by a description of the manner in which he conducts his farming operations. Mr. Budd, a civil engineer and president of the Great Northern Railway, discussed the situation of the railway industry since 1920 and stressed the importance of the contributions which mechanical engineers have made in this perfection period of railway development. His address will appear in the November issue of MECHANICAL ENGINEERING.

Entertainment and Excursions

The excellent entertainment program opened with an informal reception to President Dow on Monday evening at the St. Paul Hotel. A motion-picture film was shown which dealt with aeronautic research work carried out in Japan by means of pictures taken at the rate of 20,000 per second. Then the floor was cleared for dancing. On Tuesday, the Minneapolis members provided the program. After a visit to the flour mills, the University of Minnesota, and other important industries, the party was taken to the Woodhill Country Club on Lake Minnetonka for dinner and an evening of dancing. On Wednesday, St. Paul entertained, starting with a luncheon with the St. Paul Association of Commerce, presided over very happily by Colonel Paul Doty, a past-president of the Association and a member of the A.S.M.E. Council. President Dow spoke of the importance of the mechanical engineer and his place in modern civilization. Then after a visit to the interesting industries of St. Paul, the party returned to the St. Paul Hotel for the excellent dinner, the addresses at which were broadcast over KSTP, some delightful music, and dancing. The ladies thoroughly enjoyed the well-executed program of an able local committee. Sightseeing trips, teas, and bridge filled the time when their escorts were busy with technical matters. As this was essentially a vacation meeting, golf formed an important part of the program, and many participated in the tournament on Tuesday afternoon for which generous prizes were offered.

Council Meeting

The Council met on Monday morning with President Dow in the chair, and transacted a large volume of routine business.

TECHNICAL SESSIONS

The technical program was planned to deal with the mechanical problems of the industries of the Northwest. Ten good sessions resulted. They were held in the St. Paul Hotel on Monday afternoon, and on the mornings of Tuesday, Wednesday, and Thursday.

Aeronautics

W. B. Stout attracted a good attendance for one of the opening sessions on Monday afternoon with his address on the future of flying. He held his audience for an hour with his outline of the transportation needs that the airplane must satisfy, and the means to be taken to accomplish this. His talk will appear later in the Society publications. In the absence of the author, Mr. Stout then presented the paper on "Modern Airports and Airport Planning," by B. Russell Shaw, of St. Louis, Mo. The program was arranged by the Aeronautic Division, and L. P. Alford presided.

Applied Mechanics

At the Pittsburgh meeting in May, the Applied Mechanics Division successfully demonstrated that highly technical papers can be discussed intelligently at a meeting session. Further proof was furnished at this session, which lasted three hours and a half, under the guidance of W. E. Brooke, professor of mathematics at the University of Minnesota. The first paper, by M. G. Driessen, of Wettingen, Switzerland, giving "A Simplified Method of Determining Stresses in Rotating Disks," was read by title. Copies of this paper are available and written discussion will be welcomed. The second paper by A. B. Kinzel, on "Evaluation of the Technical Worth of a Steel From Physical Test Data," brought out several written discussions and considerable oral comment. It will also be presented at Boston in October for further discussion, and then published in Transactions. The final paper, dealing with "Stress Analysis in Electrical Rotating Machinery," by M. Stone, of East Pittsburgh, Pa., was well discussed.

Apprenticeship

S. Carl Shipley, professor of machine construction at the University of Minnesota, presided over a program arranged by the Committee on Education and Training for the Industries. The system of training and the results obtained in a cooperative program of the Tri-City Manufacturers Association were outlined by S. M. Brah, of Moline, Ill. The merits of such a program, correspondence-school instruction, and local training schools were dealt with at length in an interesting discussion. "Does Mass Production Lessen the Need for Trade Skill?" was the title of the paper by H. A. Frommelt, of St. Louis, which was presented by J. E. Nicholas. The discussion then centered on the importance of meeting the increased demand for skill in production operations.

Fuels and Materials Handling

Low-temperature distillation, the coking process, and mechanical coal mining were dealt with in this interesting session at which President Dow presided. Max Toltz, ofSt. Paul, presented some figures for the processes used in the liquefaction of the low-grade fuels found in the Dakotas and Montana. A. R. Powell, of Chicago, described the latest developments in coke-plant design, and presented some facts on the economics of the coke

industry. In the discussion the importance of local markets for the products of these two processes was particularly emphasized.

The final paper, by Eugene McAuliffe, president of the Union Pacific Coal Company of Omaha, Nebraska, valuated the various factors involved in the use of coal-loading machinery in the mines. His paper appeared in the September issue of Mechanical Engineering. In answer to a question Mr. McAuliffe stated that in 1923 his company loaded 4 per cent of its product mechanically, and in July, 1928, 56 per cent.

Agriculture

The American Society of Agricultural Engineers joined in this session, under the chairmanship of Prof. William Boss, president of the A.S.A.E. and professor of agricultural engineering at the University of Minnesota. Two splendid papers were presented by E. A. Stewart, of St. Paul, and L. J. Fletcher, of Peoria, Ill., and will be found elsewhere in this issue, together with brief summaries of the discussion they elicited.

Power

The methods of operation and the classification of costs of power systems with complicated combinations of generating units and varying load factors furnished the subject-matter of the first part of the session on power, presided over by Charles T. Sloop, professor of steam engineering at the University of Minnesota. James A. Colvin, of Minneapolis, described the method of operating an interconnected system of steam and hydroelectric plants, and Edward H. Scofield, also of Minneapolis, presented an analysis of the costs of variable-load and multiple power supply based on actual performance. In the discussion the external temperature variation of 125 deg. common in the United States was pointed out, as was also the need for watching maintenance expenses. Too low maintenance expenditures, it was emphasized, are a signal of future trouble.

The second part of the program consisted of a discussion of the hydro development of the Ohio River at Louisville, by Harrison G. Roby, of Chicago. Mr. Roby outlined the features of the Louisville station design necessitated by the conditions of navigation and flood on the Ohio River, and showed two reels of motion pictures of the plant during construction. The discussion centered on the operating efficiencies of water wheels operating under heads varying from 37 ft. to $7\frac{1}{2}$ ft.

Iron Mining

This session brought an interesting story of the historical development of mechanical mining methods in Minnesota, and a discussion of the characteristics of equipment necessary for successful operation by electricity. The two papers presented, by Anton Tancig, of Chisholm, Minnesota, and A. C. Butterworth, of Duluth, Minnesota, appeared in the September issue of Mechanical Engineering. The discussion focused on the improvement in operating conditions that had been brought about by mechanical mining devices.

Paper-Pulp Grinding and Pumping

The Printing Industries Division sponsored this valuable session on paper-mill problems, which was opened by Col. Edward T. Miller, of Chicago, with an interesting discussion on the need of more and better engineering in the printing industries. The first paper, by Adolph F. Meyer, of Minneapolis, described a method of controlling pulp-grinder operation and the resulting high economies. The second paper, by H. N. Anderson, of St. Paul, described a new pump for high-density paper stock. The discussion was informal but searching as to the merits of these two new types of apparatus.

Flour Milling

Maurice D. Bell, of Minneapolis, presented a paper on "Power in the Flour Mills at Minneapolis," which outlined the development of the use of electricity, discussed the generating problems, and told how the new apparatus had been adapted to old equipment. A. W. Strong, of Minneapolis, presided, and the discussion dealt largely with the questions of hydroelectric power generation at Minneapolis.

Research

Two papers giving the results of successful investigations were presented at this session under the chairmanship of O. M. Leland, dean of the College of Engineering and Architecture at the University of Minnesota. "Friction in Dredge Pipes," a paper by James H. Polhemus, of Portland, Oregon, and Prof. John R. du Priest, of the University of Minnesota, was presented by Professor du Priest. This paper gave new and important data on dredge-pipe friction gained in tests of 26-in. pipe with velocities up to 20 ft. per sec. Prof. Frank B. Rowley, also of the University of Minnesota, reported results from a portion of the extensive work he has been doing on insulated walls.

Local Committees

The success of the meeting was due to forty individuals from the Minneapolis and St. Paul Sections of the Society who worked valiantly under the guidance of the following executive committee: J. J. Summersby, Jr., Chairman, Lawrence Washington, Secretary, James A. Colvin, C. A. Herrick, B. J. Robertson, E. H. Scofield, W. A. Thomas, P. J. Frawley, Max Toltz, and R. K. Culbertson.

U. S. Submarine Equipment Completed

THE electrical equipment for U. S. Submarines V-5 and V-6, the largest fleet-class submarines ever built, has just been completed at the East Pittsburgh works of the Westinghouse Electric & Manufacturing Company.

The boats will be of the twin-screw type, Diesel engines being used for propulsion on the surface and direct-current motors, fed from lead storage batteries, for submerged operation. These batteries may be charged either from the propelling motors acting as generators or from Diesel-driven auxiliary generators furnished for that purpose.

The design and construction of the motors represent a radical departure from conventional methods. In a submarine, weight and space are naturally at a premium. Consequently the motors are designed in such a manner as to obtain the greatest possible amount of energy from the minimum weight and volume of material. The machines are constructed almost entirely of steel, either cast, forged or punched. Parts of the bearing housings are made of an aluminum alloy to reduce weight.

As an additional means of conserving weight and space, forced motor ventilation is used. This permits a considerably greater output from a given volume of material than obtains where natural ventilation is relied upon to dissipate the losses generated in the machine. A closed ventilating system is used, the air being cooled by passing through a special sea-water cooler. Mica and asbestos are used throughout for insulation.

Since it is essential to have ready access to the various parts of submarine motors after installation, and since it is impossible to provide sufficient clearance aboard the boats to permit complete dismantling of the motors, it was necessary to incorporate several special features of accessibility in the motor design.

Similar features of compactness, reliability and accessibility enter into the design of the generating and control apparatus.

Book Reviews and Library Notes

THE Library is a cooperative activity of the A.S.C.E., the A.I.M.E., the A.S.M.E. and the A.I.E.E. It is administered by the United Engineering Society as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West 39th St., New York, N. Y. In order to place its resources at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references on engineering subjects, copies of translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

New Books on Patent Law

PATENT LAW FOR THE INVENTOR AND EXECUTIVE. By H. A. TOULMIN, JR. Harper & Brothers, New York, 1928. Cloth 5⅜ × 7⅞ in., 288 pp., $4.

PATENT ESSENTIALS. By JOHN F. ROBB. (New and revised edition.) Funk & Wagnalls Company, New York, 1928. Cloth 5½ × 8⅜ in., 485 pp., 20 figs., $5.

THE United States Patent Office is issuing on an average of 1000 patents a week. As probably not more than one in three patents reaches the stage of issue, this means that on an average 3000 patents a week, or 150,000 a year, are applied for. These figures alone would be sufficient to indicate the large number of men who come in contact directly or indirectly with the patent situation. It is true that lawyers have a saying to the effect that any man who acts as his own attorney has a fool for a client. Nevertheless even inventors who employ an attorney would do well to master at least the fundamentals of patent law and procedure. This applies with even greater force to those who come in contact with patent law without being inventors. Business men, bankers, manufacturers, have to do so from time to time, either through investment in patents or plants making patented products, or through the necessity of buying patents or dealing with patent infringement.

The patent law is in many ways a surprising one, and this feature of it is not limited to the patent procedure alone, but to many features that might be called "outside" patent law. Thus, for example, in some states there is a law to the effect that a note given in payment for a patent can be collected only if it bears on its face the stipulation "given for a patent right." For passing a note not bearing such a stipulation one state imposes a fine of $500—and a jail sentence of forty days. This shows the extraordinary complexity of the laws governing patents and patent rights.

Because of the large numbers directly and indirectly interested in this matter, quite a literature on the subject has grown up. Two such books have appeared recently. One, by H. A. Toulmin, Jr. is entitled, "Patent Law for the Inventor and Executive." In this book the author does not try to go into the minutiae of patent law and teach how to obtain a patent. He presupposes that this will be done with the help of a proper attorney. He does, however, discuss in considerable detail what might be called the "policy" of patents. The book is primarily addressed not to the inventor himself but to those who have to buy and sell patents, operate under them, and at times infringe them. Engineers will be particularly interested in the chapters dealing with the election of "trade secret or patent," ownership of inventions by employees and stimulation of invention by them, and the relation between patents and anti-trust laws. The appendices give in abstract some of the patent laws but do not cover the most recent amendments which are, however, not of primary importance.

The book by John F. Robb on "Patent Essentials" is for an entirely different purpose. While primarily addressed to the engineer and inventor it is sufficiently complete to be of value to the patent attorney, and indeed presupposes in the reader a greater interest for the legalities of patent procedure than the average—what might be called "incidental"—inventor would be apt to have. To a person, however, who must know more about patent procedure than a man who applies for only one patent in all his life, the book will prove of decided interest. It is believed that the chapter entitled, "The Science of Drafting Patent Claims," will be of practical interest both to engineers and patent attorneys. While a vast amount of material in the way of court decisions has accumulated on the subject of validity and propriety of patent claims, the matter has not been dealt with before in a systematic manner in any publication, and the treatment by the present author is decidedly enlightening. The present publication is a revised edition.

Books Received in the Library

ABMESSUNGEN VON HOCH UND MARTINOFEN. By Michael Pavloff. Otto Spamer, Leipzig, 1928. Paper, 7 × 10 in., 148 pp., tables, diagrams, 7 × 10 in., 14 r.m.

A practical textbook on the design of blast furnaces and open-hearth steel furnaces, intended for students of metallurgy and for furnace designers. Following the usual method of the author, the book is founded directly on practice, the dimensions suggested being derived from extensive study of actual furnaces. The book will be welcomed by all designers having to deal with its subject-matter.

THE ELEMENTS OF INDUSTRIAL ENGINEERING. By George Hugh Shepard. Ginn and Co., Boston, 1928. Cloth, 6 × 9 in., 541 pp., diagrams, tables, $4.80.

In the preparation of this work the writer had three distinct purposes: (1) to reduce industrial engineering to a few definite and comprehensive principles, by which the engineer can analyze any situation in management and synthesize the procedure; (2) to bring students immediately into working contact with these principles; and (3) to cause them to learn the principles practically by using them in their daily lives.

Some of the chapter headings are as follows: III-Campus Activities as Part of a Student's Education; V-Adaptation of Conditions and Work to Each Other; IX-Higher Common Sense; XI-Personnel; XII-Organization; XIII-Standards; XV-The Fair Deal.

ENGINEERS. Neo-Technical Research Corporation, New York, 1928. Cloth, 9 × 12 in., illus. diagrams, tables, $25.

This book lists the engineers in corporations with their official duties and connections. It gives the essential engineering data for each branch of engineering, and a directory of materials and equipment for industrial and power plants. There is also a section devoted to mathematical tables and a list of universities of engineering with the names of the presidents and the engineering faculty. The book is divided into five sections, separately paged.

ENGINEERING AERODYNAMICS. By Walter S. Diehl. (Ronald Aeronautic Library.) Ronald Press Co., New York, N. Y., 1928. Cloth, 6 × 9 in., 288 pp., illus., diagrams, $5.

This book has been written to supply the demand for more practical information on aerodynamics in form suitable for direct application by aircraft designers and advanced students in aeronautical engineering. The author has tried to include as much new material as possible and to avoid the inclusion of well-known or easily obtained data. The conventional treatment of elementary aerodynamical problems has been omitted.

FORCE ACCOUNT ON UNIT-PRICE CONSTRUCTION CONTRACTS, a Report by the Bureau of Municipal Research of Philadelphia. Philip A. Beatty in charge of this study. Thomas Skelton Harrison Foundation, Philadelphia, 1928. Paper, 6 × 9 in., 35 pp. (Copies of the Report may be obtained without charge from the Bureau.)

The Bureau of Municipal Research is engaged in a study of the methods followed in Philadelphia in preparing, letting, and performing contracts for municipal work. The present pamphlet presents its finding and recommendations about force-account practices in various departments of the city government. The pamphlet analyzes practices in some twenty American cities and discusses the advantages and disadvantages of the different methods. Recommendations for controlling force accounts are given. As little has previously been published on this subject, the pamphlet should interest many.

A HANDBOOK OF PETROLEUM, ASPHALT AND NATURAL GAS. By Roy Cross. (Bulletin no. 25, revised.) Kansas City Testing Laboratory, Kansas City, Mo., 1928. Leather, 5 × 7 in., 832 pp., tables, diagrams, $7.50.

A very convenient pocketbook for oil men and others interested in petroleum. The author has brought together in condensed form a great mass of technical and scientific information on the production, properties, handling, refining, and evaluating of petroleum, asphalt, natural gas, and oil shale. Particular attention is paid to refining and cracking. A valuable list of patents on cracking is included, and there is a good bibliography. The present publication is a revision of earlier issues, with additions.

MACHINE SHOP UNIT. Edited by H. C. Thayer. Part 1, Processes 1 to 12. McGraw-Hill Book Co., New York, 1928. Paper, 9 × 11 in., diagrams, $0.35.

A collection of process sheets prepared by a group of instructors in vocational schools, to assist in teaching basic operations of machine-shop work. The present collection cares for twelve operations on the lathe, taken from Burghardt's "Machine Tool Operation," and intended for use with that text.

THE MANUFACTURE OF ARTIFICIAL SILK WITH SPECIAL REFERENCE TO THE VISCOSE PROCESS. By E. Wheeler. (Monographs on Applied Chemistry.) Van Nostrand, New York, 1928. Cloth, 5 × 9 in., 150 pp., illus., diagrams, $5.

The author states that this monograph is not an exhaustive treatise on the subject, but its object is to present a description of the essential chemical and engineering details of the modern methods of manufacturing and of the properties and uses of artificial silk. References to patents and periodical literature are given at the end of each chapter.

MATHEMATICS IN LIBERAL EDUCATION. By Florian Cajori. Christopher Publishing House, Boston, 1928. Cloth, 5 × 8 in. $1.50.

This book is a review of the statements of prominent men of all ages on the effect of methematics in liberal education. In this historical study of the question, the author has quoted names and opinions of those in favor of mathematics as well as those opposed to mathematics.

MECHANICAL ENGINEERING, A Text-Book for a Short Course. By W. A. Mitchell. John Wiley & Sons, New York, 1928. Cloth, 6 × 9 in., 402 pp., diagrams, $4.

This book has been prepared for the cadets of the United States Military Academy. It is intended to teach the cadet enough of the principles of mechanical engineering so that he may in the future understand the practical engineering requirements of his profession.

MODERN PICTURE THEATRE ELECTRICAL EQUIPMENT AND PROJECTION. By R. V. Johnson. Second Edition. Crosby Lockwood & Son., London, 1927. Cloth, 6 × 9 in., 189 pp., illus. diagrams, 10 s. 6 d.

This is not a scientific textbook, but it is intended for architects, theater owners, theater operators, and electricians. It takes up primary, secondary, and effect lighting of theaters, the motion-picture projection room and projection machine, with all the necessary electrical equipment.

PETROLEUM AND ITS PRODUCTS. By William A. Gruse. McGraw-Hill Book Co., New York, 1928. Cloth, 6 × 9 in., 377 pp., $4.50.

This book starts with a general description of the types of petroleum, their chemical constitution, physical properties, and origin. The author then discusses refining by distillation, chemical methods, adsorption, and cracking. The last part includes gasolene and motor fuels, kerosene, lubrication and petroleum lubricants, petroleum wax and petrolatum, fuel oil, petroleum asphalts and miscellaneous petroleum products. It is intended as a textbook on the chemistry of American petroleum.

PHYSICAL AND CHEMICAL EXAMINATIONS OF PAINTS, VARNISHES, LACQUERS AND COLORS. By Henry A. Gardner. Fourth edition. Institute of Paint and Varnish Research, Washington, D. C., 1927. Cloth, 6 × 9 in., 781 pp., +apx., illus., tables, $11.

An exhaustive summary of approved methods for testing the raw materials and the finished products of the paint, varnish and lacquer industries, prepared by an authority in this field. An appendix contains twenty-nine specifications for painting products prepared by the Federal Specifications Board to govern Government purchases.

PRACTICAL SHEET METAL DUCT CONSTRUCTION. By William Neubecker. Fourth edition, Sheet Metal Publication Co., New York, 1928. Cloth, 6 × 8 in., 225 pp. illus., diagrams, $3.

This book relates to the construction and erection of heating and ventilating ducts, registers, and dampers. It illustrates the method of calculating areas of pipes and ducts, and the construction of a large ventilator. It also describes the design and layout of duct fittings and the method of taking off quantities of material in duct work.

PRINCIPLES OF MECHANISM. By F. Dyson. Oxford University Press, American Branch, New York, 1928. Cloth, 6 × 9 in., 296 pp., diagrams, $4.25.

The author has written this book for students studying the fundamental principles of moving parts of machines. No attempt has been made to apply the principles involved to the design of actual machines. The text contains examples with their

solutions and problems have been placed at the end of each chapter.

DIE PUMPEN, EIN LEITFADEN FÜR HÖHERE MASCHINENBAUSCHULEN UND ZUM SELBSTUNTERRICHT. By H. Matthiessen and E. Fuchslocher. Second edition. Julius Springer, Berlin, 1928. Cloth, 6 × 9 in., 90 pp., diagrams, 2.90 r.m.

In the brief compass of ninety pages, this book presents admirably the essentials of the arrangement, construction and operation of the most-used forms of pumps. The exposition is confined to practical matters, a knowledge of pump theory being left to other texts. The book is intended to supplement the instruction in engineering colleges and for self-instruction.

REGELN FÜR LEISTUNGSVERSUCHE AN KREISELPUMPEN. By a Committee of the Verein deutscher Ingenieure and the Kreiselpumpen-Verband. V.D.I. Verlag, Berlin, G.M.B.H., 1928. Paper, 8 × 11 in., 27 pp., diagrams, tables, 3.50 r.m.

The rules for testing centrifugal pumps given in this pamphlet have been formulated under the auspices of the Society of German Engineers, by a committee of engineers, users, manufacturers and scientists, and are intended as standards for such tests. The principles involved, the methods of testing and the interpretation of the results are discussed fully, the necessary data are given, and their use illustrated.

TECHNISCHES HILFSBUCH. Edited by Schuchardt & Schütte. Seventh edition. Julius Springer, Berlin, 1928. Cloth, 5 × 7 in., 526 pp., illus., tables, diagrams, 8 r.m.

A pocket book for machinists and mechanical engineers, which gives in convenient form much information on standards for screw threads and machine parts, on the properties of metals and the capacities of machine tools, and on shop practice in general. The work is an unusually well selected collection of data.

TEXTILE MICROSCOPY. By L. G. Lawrie. Ernest Benn, Limited, London, 1928. Cloth, 7 × 10 in., 144 pp., illus., diagrams, 25 s.

This volume takes up special applications of the microscope in textile work. Detailed descriptions are given of various types of books and accessories, such as lamps and light filters. It includes microscopic technique for handling fibers, and the different stains that may be used.

TRAITE-PRATIQUE DE NAVIGATION AÉRIENNE. By A. B. Duval and L. Hébrard. Gauthier-Villars & Cie, Paris, 1928. Paper, 7 × 10 in., 196 pp., diagrams, plates, 30 fr.

Duval and Hébrard's "Practical Treatise on Aerial Navigation" was, we believe, the first to appear on that subject. Originally printed serially in *L'Aéronautique* several years ago, it later appeared in book form. The second edition is now published, with revisions bringing it up to date.

The book presents the technical methods of navigation, as adapted from those which maritime navigators have found satisfactory. The treatment is elementary. The use of the compass and other instruments is explained, the general rules of navigation are given, and methods are outlined.

WATER PURIFICATION. By Joseph Ellms. Second edition. McGraw-Hill Book Co., New York, 1928. Cloth, 6 × 9 in., 594 pp., illus., tables, plates, diagrams, $3.

A comprehensive treatise on the purification of water by an engineer of wide experience. The entire subject is covered, and practical information is given on the design, construction, and operation of filtration plants, and costs are included freely. Bibliographic references are provided amply.

The new edition, which is about one-fourth larger than the first, has been carefully revised and brought up to date. A new chapter on the effect of the hydrogen-ion concentration of natural waters has been added.

WECHSELSTROM-KOMMUTATORMASCHINEN. By Karl Baudisch Walter de Gruyter & Co., Berlin, 1928. Cloth, 4 × 6 in., 104 pp., illus., diagrams, 1.50 r.m.

Takes up the method of operation and the application of commutator machines, the commutator armature and its properties, and single and polyphase commutator motors.

Synopses of A.S.M.E. Transactions Papers

THE papers abstracted on this and following page appear in the Wood Industries and Petroleum sections of A.S.M.E. Transactions as published in its new form. These sections have been sent to all who registered in the Wood Industries and Petroleum Divisions. Other sections are in the course of preparation and will be announced, when completed, in later issues of "Mechanical Engineering."

WOOD-INDUSTRIES PAPERS

Change in Moisture Content of Lumber During Rail Shipment

BY G. E. FRENCH

U. S. Forest Products Laboratory, Madison, Wis.

THIS paper presents the results of an investigation made to determine whether or not lumber placed aboard cars at the sawmill at a low moisture content will change in moisture content during transit to such a degree as to defeat the purpose of careful seasoning for general or specific uses.

The results of the investigation show that stock placed in the car in satisfactory condition as to moisture content will reach the unloading point in practically the same condition. If, on the other hand, it is received in bad condition by the consignee, the fault, unless the car is found to be in a poor state of repair, must be with the seasoning methods which have been employed. [Paper No. WDI-50-8]

The Need of Research on Tropical Woods Before Marketing Them

BY ARTHUR KOEHLER

In charge, Office of Wood Technology, Forest Products Laboratory, Madison, Wis.

AFTER establishing the value of research in woods over cut-and-try methods of determining their properties and values, the author discusses two main lines of research which should be

carried on with tropical woods, the determination of the normal properties of the species of wood, and the determination of means of overcoming objectionable qualities that may appear in the species. [Paper No. WDI-50-9]

Our Need for Knowledge of Tropical Timbers

BY SAMUEL J. RECORD

Professor of Forest Products, Yale University, New Haven, Conn.

RAPID waning of supplies of virgin timber in this country calls for extended use of tropical woods, whose properties and uses must become familiar to the industry. The work that is needed to be done is carefully outlined. The agencies to do it are available and willing. It remains for those who would profit most from these investigations to furnish the means for carrying them out. [Paper No. WDI-50-10]

Problems of Design for Mass Production in The Furniture Industry

BY BAYARD EDWIN RICHARDSON

Plant Engineer, Stow-Davis Furniture Co., Grand Rapids, Mich.

THIS paper discusses the problem of design for mass production in the manufacture of commercial furniture.

All previous conceptions of structural design have been abandoned, and while external appearance has been only slightly altered, the component parts of the desk have been radically changed.

These changes in structural design have brought about marked reductions in manufacturing costs, greater strength in the assembled products, and best of all, a method of assembly which permits the use of the principles of mass production now so successfully used in the automotive industry. [Paper No. WDI-50-11]

Compressive Tests of Balsa Wood

BY A. H. STANG

Engineer, Bureau of Standards, Washington, D. C.

THIS paper gives the results of physical tests made on eleven samples of balsa wood. Stress-strain and steam-set curves are given, as well as a table of the physical properties as revealed by the tests. [Paper No. WDI-50-12]

PETROLEUM PAPERS

Progress in the Petroleum Industry

THIS report of the Petroleum Division is subdivided in such a way that various phases of the division's activities are treated individually by prominent engineers. The report contains the following: "Progress in the Production of Oil," by Homer R. Pierce; "Development of Mechanical Equipment for Petroleum Production," by Hollis P. Porter; "Progress in Rig and Field Equipment," by Glenver McConnell; "Progress in the Natural Gas Industry for 1926–1927," by H. B. Bernard; "Development of Transportation of Crude Oil in 1927," by B. P. Sibole; and "Progress in Refining," by Walter Samans. [Paper No. PET-50-1]

General Heat-Transfer Formulas for Conduction and Convection

BY EDWIN R. COX

Engineer, California Gasoline Co., Los Angeles, Calif.

STARTING with the work of Osborne Reynolds and Nusselt, the author sets up the equation developed by the latter and reviews the work of other investigators such as Rice, McAdams, and Frost, the Babcock and Wilcox Company, and others on the same subject. [Paper No. PET-50-2]

The Gas Lift as Applied to Oil Production

BY F. W. LAKE

Superintendent of Production, Union Oil Co. of Calif., Brea, Calif.

THE central-plant system of gas-lift operation is described, and production-decline curves of several California wells showing the results of the process are discussed. The factors which control successful operations are enumerated, and a statement of the limitations of the process is made. [Paper No. PET-50-3]

NOTE: Those who have not registered in the A.S.M.E. Wood Industries and Petroleum Divisions, whose papers are abstracted on this and previous page, and who desire copies of any of these papers, may obtain them by using the form given below.

TO THE SECRETARY, A.S.M.E., 29 West 39th Street, New York, N. Y. Date.....

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